FMS Flight Simulator Encoder

RIAA Preamp with FETs

64-K 80C552 Flash Board

LED Roulette
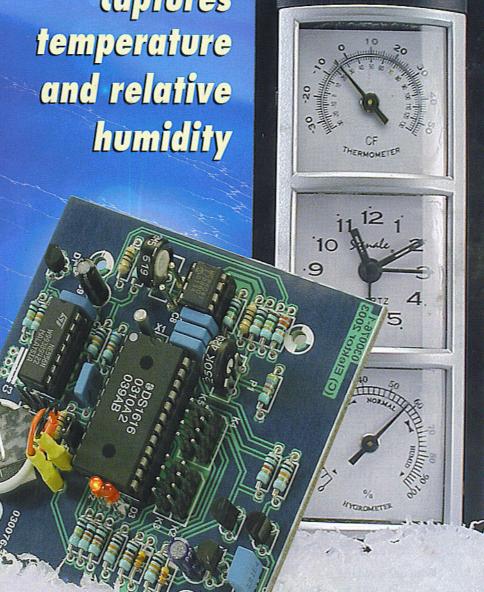
OTL Headphone Amp

Multi-event Alarm Clock

CLIMATE LOGGER

captures temperature and relative humidity

Technical Queries
We can only answer questions or remarks of general interest to our
readers, concerning projects not older than two years and published in
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microcontrollers, GALs, PALs, FPGAs and EPROMs. All other parts for
building our projects should be purchased from kit/component suppliers
advertising in this magazine.
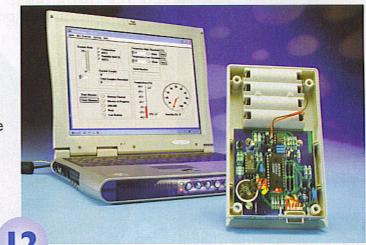
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CONSTRUCTION PROJECTS

Climate Logger

This electronic alternative to mechanical temperature and humidity
recorders is a very compact standalone unit which draws very little
current. The Dallas DS1616 device used comes already equipped with
a temperature sensor, and besides a humidity sensor we can add a
range of other sensing devices. The collected data can be transferred
to a PC or
notebook over an
RS-232 port for
analysis by user-
friendly Windows
software. The
system can also be
connected to a
microcontroller
board.

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FMS Flight Simulator Encoder

With the FMS R/C Flight Encoder described here you can
polish your flying skills and gain the valuable experience you
need without having to invest in a radio control or even to
build a model airplane. In fact the FMS
encoder will even allow you to use your
own radio control to further enhance
your flying ability.

22
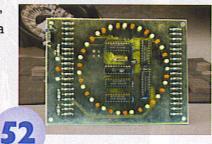
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LED Roulette

Everybody gambles sometimes, perhaps in a lottery or even in a casino. After all, who doesn't dream of becoming rich without having to work hard?

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From all at Elektor Electronics: a happy, healthy, peaceful and prosperous 2004!

64-K 80C552 Flash Board

This microcontroller board is a standard 8051-based system, with a few extras that make it suitable for use as a development system or control module for a larger system. Its most important features in this regard are on-board Flash memory programming via the serial RS232 port, direct on-board program debugging and low cost.

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INFORMATIVE ARTICLES

The Sense Resistor

56

Sense resistors in series with the load are central to regulating current in switch-mode power supplies. It is possible to optimise the power loss in these resistors, as we show with an example converter circuit that drives eight white LEDs from a 4.8 V battery.

Success in his Pocket!

Michael Birmingham, from Calday Grange Grammar School, Wirral, attained the top mark in this year's AQA A Level Electronics examinations and so qualified for this year's top candidate award.

Michael is interested in computing, sports and socialising with friends. He says that he found the AQA Electronics course very interesting and especially enjoyed the practical coursework.

In honour of Michael's achievement, his school has been awarded a free one year's subscription to Elektor Electronics magazine.

This award is sponsored by European Electronique, one of the largest resellers of IT equipment in the UK, and consisted of a Hewlett Packard IPAQ Pocket PC.

Michael, who completed his other A level courses with A grades in Maths, Further Maths, Physics and General Studies, is taking a gap year with the Smallpeice Trust. This will take him to Plymouth University for a 3 month Engineering course, followed by a month's language course in France before a 3-month work placement in Finland, probably with the Ericsson Company. When he completes his gap year, Michael will take up his place at Girton College, Cambridge to read Engineering.

About AQA

AQA is one of the three unitary awarding bodies within England. The GCE A Level in Electronics is a two year course and is part of Curriculum 2000. It consists of two distinct parts — the AS Level, which is the first year of the two years and the second year A2 course which, together with the AS course, forms the complete A Level award.

Students would normally study this course after completing their GCSE qualifications when they are 16 years old.

The whole specification assumes a systems approach to Electronics and that the candidates will undertake significant practical work.
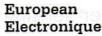
The AS Level course is split into two modules which cover the basic building blocks used in Electronics; logic gates and systems, amplifiers, input sensors, output devices, output drivers, astable and monostable circuits, counters etc.

The AS Level assessment consists of two written examinations each lasting one and a half hours together with an externally moderated coursework project worth 30% of the overall marks for the award.

The A2 course builds upon these basic building blocks and applies them to Electronic and Computer Control systems for one module and Communication systems for the second. The A2 Level assessment has the same form as the AS assessment but is focussed on the subject content of the A2 specification. The specifi-

cations for all of the AQA subjects can be found on the AQA web site www.aqa.org.uk

European Electronique

In order to promote the study of Electronics, European Electronique, one of the largest resellers of IT equipment in the country, agreed to sponsor a prize for the candidate who gained the highest marks overall in the A Level award. This is the second year of the award, which each year, so far has consisted of a Palm top computer.

The company web site is at www.euroele.com

(047005-1)

New Legislation Threatens Electrical / Electronics Firms

The environmental support and advisory service, Envirowise, recently expressed serious concern over the apathy being shown by many UK electrical, electronics, telecommunications and computer manufacturers towards impending new EC legislation on waste electrical and electronics equipment and hazardous substances.

Continuing failure by companies to get to grips with the business actions needed to tackle the directives on WEEE (Waste Electrical and Electronic Equipment) and ROHS (Restriction Of use of certain Hazardous Substances) has

serious implications for the whole industry and could jeopardise the UK's future position in the global marketplace.

The DTI and DEFRA support an Envirowise campaign to alert the managing directors of UK electrical and electronics companies to the problem. The campaign is also being backed by leading UK companies, including British Telecom, Fujitsu and Sony, and the electrical / electronics industry trade association, Intellect.

Already it is estimated that the future estimated costs of the EC legislation to the UK economy could be as much as £455

million a year for WEEE and some £200 million a year for ROHS legislation. This will lead to an average cost increase of 1 to 2% for many products and as much as 3 or 4% for some larger or more complex products. Apathy could fuel even greater cost increases and render many UK companies uncompetitive. Some may even find that their products are banned from sale. Envirowise believe that much of the problem stems from the fact that companies have so far only thought of the legislation as a simple environmental requirement that needn't be

addressed until some ROHS substances are banned in 2006. The reality is that the legislation requires serious forward planning and financial, marketing and design decisions, and isn't something that managing directors can delay or simply gloss over.

Envirowise is supporting the campaign via its website (www.envirowise.gov.uk), with advice through the Environment and Energy Helpline (telephone 0800 585794) and through its FastTrack and DesignTrack visiting services.

(047007-1)

Climate Logger
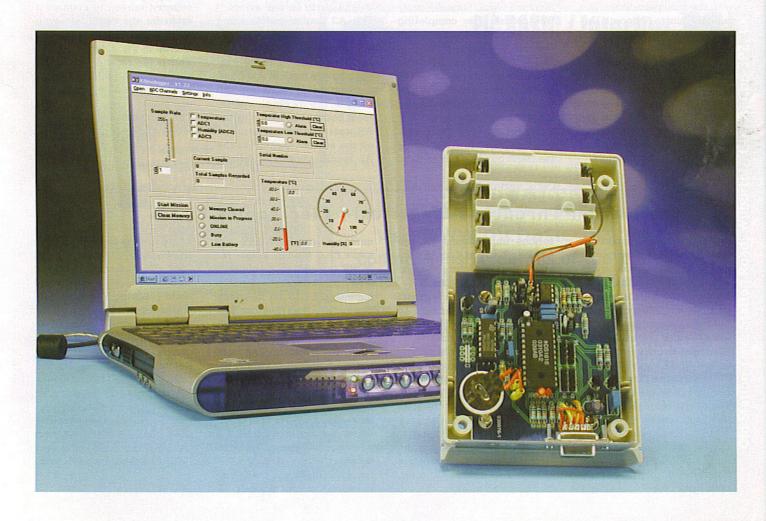
Recording temperature and humidity

Design by T. Poms

http://chripo.icb.at/Rooney

This electronic alternative to mechanical temperature and humidity recorders is a very compact standalone unit which draws very little current. The Dallas DS1616 device used comes already equipped with a temperature sensor, and besides a humidity sensor we can add a range of other sensing devices. The collected data can be transferred to a PC or notebook over an RS-232 port for analysis by user-friendly Windows software. The system can also be connected to a microcontroller board.

The climate logger operates completely autonomously while it is carrying out a 'mission' (measurement sequence), and can run on battery power for a long period in this mode. The device can, for example, be left in the refrigerator or in the wine cupboard to continuously record the temperature and humidity. The Windows-based software running on a PC is used not only after a mission to download and analyse the stored data, but also before a mission to configure the data logger. With the aid of the software, both the sample rate and the selection of which channels are to be recorded can be configured.

The version of the climate logger described here connects to the PC over a serial interface. The planned USB version previewed last month is still in development.

DS1616

'Intelligent' temperature sensors produced by Dallas frequently appear in circuits in *Elektor Electronics*. There is a wide range of ICs offering a wide range of peripherals, so that the ideal device can easily be found to match the requirements of any particular application. A built-in memory comes in very handy for building a temperature logger. The DS1616 device used here is a particularly well-equipped member of this series of temperature sensors.

The internal block diagram of the DS1616 is shown in **Figure 1**. Besides the temperature sensor and the memory the most interesting feature is certainly the analogue-to-digital converter, which has a resolution of 8 bits. The converter is equipped with a 3-to-1 input multiplexer. It is possible to use the converter to accurately measure three external voltages in the range 0 V to 2 V, and to store them along with the internal temperature signal.

The DS1616 also offers a real-time clock driven from a built-in oscillator (which requires a 32.768 kHz watch crystal). The clock is also used to drive a simple serial RS-232 interface to allow alarm times, sampling clock rates, timestamps and time delays to be retrieved from the device's memory. It is also required for scanning the measurement channels and is
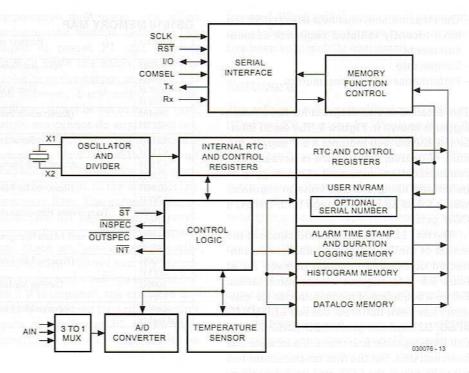
Figure 1. Internal circuit of the DS1616.

needed for certain commands such as *Clear Memory* to be carried out.

The DS1616's built-in temperature sensor determines the operating temperature range of the climate logger at –40 °C to +80 °C. The components used for the remainder of the circuit, including the humidity sensing circuitry, must also be specified for at least this temperature range, or the overall specifications of the climate logger will be degraded (**Figure 2**).

Memory Map

The DS1616 offers 2048 bytes of memory divided into pages of 32 bytes each (**Figure 3**). The *RTC and Control Registers* and the *User NV RAM* areas can be written to. The use of the RTC and control registers in our climate logger application will be discussed further in the 'Software' section below. All the other locations can only be read. Each read command contains the start address from which reading is to begin, and data are then transmitted until the end of the page is reached. This means that each read command will cause a maximum of 32 bytes, plus a 2-byte CRC generated in hardware by the DS1616, to be sent to the master device (a PC in this case). The

CRC (cyclic redundancy check) allows errors in transmission to be detected, so that the command can be repeated if necessary.

The RAM is non-volatile (NV), which means that the memory contents are preserved even when power is lost. This RAM is used to store important parameters when the master software is exited: these values can then be reloaded by the software when it is restarted at a later date. The following parameters are stored by the current version of the software:
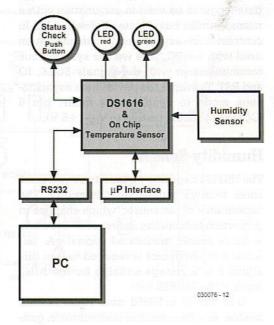
Figure 2. Block diagram of the Climate Logger.

– The measurement channels selected for the most recently initiated sequence of measurements
– Sample rate
– Performance-related parameters

The detailed circuit diagram for the climate logger is shown in **Figure 4**. The serial interface of the DS1616 requires a 5 V supply, but only, of course, when there is actually any communication occurring. This supply is generated using a 78L05 voltage regulator which takes its input voltage from the PC's COM port.

The two LEDs provide an indication of the status of the DS1616. The pushbutton connected across JP1 must be pressed for at least 0.5 s to request status information. Before a sequence of measurements (or 'mission') has been initiated, the red LED ($\overline{\text{OUTSPEC}}$, D2) and the green LED ($\overline{\text{INSPEC}}$, D3) will flash together four times. If a mission has been initiated, but the first measurement has yet to be taken, the LEDs will flash four times alternately, starting with the red LED. A sequence of measurements can be initiated either from the PC, or, in standalone operation, by pressing the pushbutton. See also the software description below and the guide to operation at the end of this article.

The software allows threshold values to be defined. If a measured analogue value (an external voltage or a reading from the temperature sensor) is above (or below) the threshold value, a bit is set in the Status 1 register. When this happens, the red LED (D2) flashes four times. If the user-defined thresholds are not crossed, the green LED (D3) will flash four times.

An interface is also provided to allow the data logger to be used in conjunction with a microcontroller board instead of with a PC. In contrast to the asynchronous communication used with the PC, here we use synchronous communication with the signals SCLK, IO and RST. To switch the device from asynchronous mode to synchronous mode, pin 6 (COMSEL) should be tied to V_{CC} (+5 V).

Humidity Sensor

The HS1101 capacitive humidity sensor measures relative atmospheric humidity. The capacitance of the sensor, which changes in proportion to humidity, is first converted into a pulse-width modulated signal. A fair amount of electronics is required to turn this signal into a voltage suitable for the AIN2 input of the DS1616.

One half of a TS556 dual timer is connected as a free-running multivibrator, generating a regular squarewave signal. The RC-

DS1616 MEMORY MAP

Address	Register definition	Page(s)
0000H 003FH	RTC and Control Registers	0 – 1
0040H 005FH	User NV RAM	2
0060H 0217H	(Reserved for Future Extensions)	3 – 16*
0218H 021FH	Serial Number	16**
0220H 027FH	Alarm Time Stamps and Durations	17 – 19
0280H 07FFH	(Reserved for Future Extensions)	20 – 63
0800H 087FH	Temperature Histogram (63 Bins of 2 Bytes Each)	64 – 67
0880H 08FFH	ADC Channel 1 Data Histogram (64 Bins of 2 Bytes Each)	68 – 71
0900H 0FFFH	(Reserved for Future Extensions)	72 – 127
1000H 17FFH	Datalog Memory (64 pages)	128 – 191
1800H and higher	(Reserved for Future Extensions)	192 +

*   First 8 bytes
** Last 8 bytes

Figure 3. DS1616 memory map.

combination formed by R1, R2 and C1 sets the period at about 1 s. IC1.A triggers the second half of the timer, which operates as a monostable multivibrator, creating a pulse-width modulated waveform. At its output we have a lowpass filter which finally turns the PWM signal into an analogue DC voltage proportional to the atmospheric humidity. Depending on the characteristics of the sensor, this voltage varies from approximately 990 mV to 1190 mV. The signal must now be processed so that it lies in the range 0 V to 2 V, so that good accuracy can be obtained using the analogue inputs of the DS1616. According to its datasheet, the sensor capacitance only varies between 161 pF and 200 pF, and the electrolytic capacitors used have a wide tolerance: this means that the circuit will require calibration.

This facility is provided using instrumentation amplifier IC3, which amplifies the generated voltage by a factor of 10. Very high resistances are used here in order to keep current consumption low. The output signal is also passed through a high-value resistor before being taken to the analogue input of the DS1616.

The voltage VCC$_{\text{HUM}}$ is generated using an LM385-2.5. This pro-

duces a fixed reference from the varying battery voltage, used to supply the whole humidity measurement circuit as far as IC3. This ensures a good power supply rejection ratio (PSRR) figure.

A Compact Data Logger

The climate logger is constructed on a single-sided printed circuit board (**Figure 5**). There are no wire links, and construction should not present any difficulties. The ICs should be fitted in sockets. Terminals are provided for all the external connections, including for the 9-way sub-D socket for the RS-232 interface, and for the two batteries BT1 and BT2. BT1, which powers the humidity measurement circuit, has to supply a considerably greater current than 'backup battery' BT2, which only supplies the DS1616 when it is in autonomous mode. This means that BT1 should be made up from AA or C cells in series, whereas BT2 can just be a coin cell (see also the text box). BT2 also determines how long as the climate logger can retain its stored data and settings, while, BT1 only determines for how long humidity measurements can be taken.

The enclosure must not only house the printed circuit board, but

also the batteries and their holders, the pushbutton, and the RS-232 socket. The humidity sensor should be soldered as close as possible to K1. It is not recommended to mount the sensor on the side of the enclosure, since this will involve a greater cable length. The enclosure should not be airtight so that atmospheric humidity is present at the humidity sensor.

Calibration

Two reference capacitors (or combinations of capacitors) of 161 pF and 200 pF are required for alignment. The values should be checked directly by measurement. First connect the 161 pF capacitor to K1, and measure the voltage at the output of the lowpass filter using a high-

impedance multimeter. The offset voltage (the voltage between the input of preset P1 and ground) should have the same value. The voltage at the output of IC3 should be between 2 mV and 7 mV. The voltage cannot be set to exactly zero, since we cannot do anything about the offset voltage of the operational amplifier. Now connect the second capacitor to K1 and once more measure the voltage at the output of the lowpass filter. The value should be about 200 mV higher than the previous reading with the smaller capacitor. Since we have a voltage variation of about 200 mV over the humidity range, and a voltage range of 0 V to 2 V is required, the amplifier circuit is configured for a non-inverting gain of 10. Preset P2 at the non-inverting input allows the gain to be

trimmed. When 2.00 V is measured at the output of the operational amplifier, calibration has been successfully completed.

Software

The software runs under Windows 2000 and Windows XP; versions for Windows 95 or 98 are not currently available but may be developed later (watch the author's website). The main window allows control over the main settings and shows real-time measurement results (**Figure 6**). The measurement channels (temperature, ADC1, humidity/ADC2 and ADC3) can be individually enabled and disabled. When the DS1616 is not 'on a mission', the temperature and humidity values are measured once per second (assuming the corresponding measurement channels are enabled) and the results displayed. This feature is implemented using a timer whose default period is one second. However, this
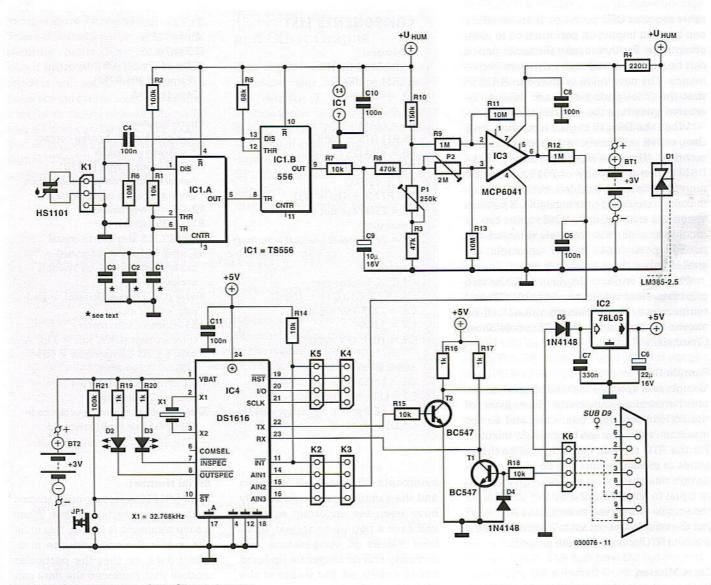
Figure 4. Circuit diagram of the Climate Logger.
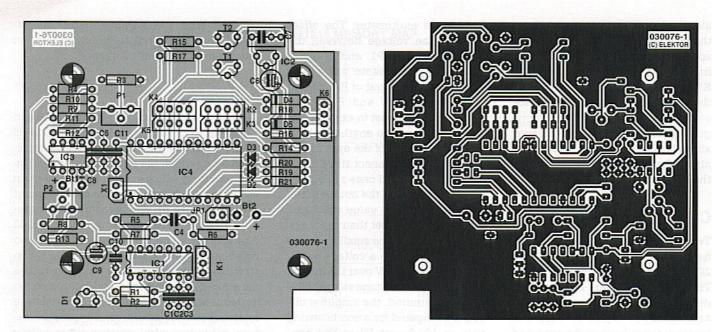
Figure 5. Layout and component mounting plan for the single-sided printed circuit board.

timer requires CPU power to operate, which can have an impact on performance in older computers. For this reason the timer period can be set as desired under *Settings/Performance*. The new value is stored in RAM so that the timer period does not need to be entered every time the software is started up.

When the DS1616 begins a mission, only the active channels are sampled and recorded. The data logging memory of the DS1616 has a capacity of 2048 bytes. The more channels are enabled, the shorter the maximum recording time available. If just one channel is enabled, up to 2048 values can be recorded; with two channels enabled the maximum is 1024. If four channels are enabled, then the maximum is 512.

The main window displays only the two most important values: humidity (ADC2) and temperature. The remaining values can be shown by selecting *ADC Channels/Show Channels*.

Sample Rate

'Sample rate' specifies the time interval in minutes between measurements. The registers of the DS1616 are eight bits wide, and so the maximum value that can be set is 255 minutes. For the RTC to work correctly, and so that a series of measurements can be initiated, the sample rate must be set to a value greater than or equal to one. When the battery is changed the sample rate is reset to zero; if the RTC is set but the sample rate not set to a value of at least one, the RTC will not operate properly.

Start Mission

This button initiates a sequence of mea-surements. The enabled channels and the sample rate should already have been set: incorrect settings will case a pop-up to appear. Real-time values of temperature and humidity will no longer be updated once per second, but rather at the preset sample rate.

Serial Number

Each DS1616 is factory-programmed with a unique serial number. When a save command is issued, this number is stored along with the measured data, so that the particular module that produced the data can be identified.

COMPONENTS LIST

Resistors:
R1,R7,R14,R15,R18 = 10kΩ
R2,R21 = 100kΩ
R3 = 47kΩ
R4 = 220Ω
R5 = 68kΩ
R6,R11,R13 = 10MΩ
R8 = 470kΩ
R9,R12 = 1MΩ
R10 = 150 kΩ
R16,R17,R19,R20 = 1kΩ
P1 = 250kΩ preset (vertical mounting)
P2 = 2MΩ preset (vertical mounting)

Capacitors:
C1,C2,C3 = see text
C4,C5,C8,C10,C11 = 100nF
C6 = 22µF 16V radial
C7 = 330nF
C9 = 10µF 16V radial

Semiconductors:
D1 = LM385-2.5
D2 = LED, red, 3mm, low-current
D3 = LED green, 3mm, low-current
D4,D5 = 1N4148

T1,T2 = BC547
IC1 = TS556
IC2 = 78L05
IC3 = MCP6041-I/P (Microchip)
  (Farnell # 396-8790)
IC4 = DS1616

Miscellaneous:
JP1 = pushbutton, 1 make contact
K1 = 3-way pinheader
Humidity sensor type HS1101
  (www.humirel.com), available from
  Unitronic (www.unitronic.de)
K2-K6 = 4-way pinheader
BT1 = 3V Lithium cell
X1 = 32.768 kHz quartz crystal
BT2 = 2 UM-5 (AM-5) or AA
  batteries (depending on available
  enclosure)
9-way sub-D socket (female), angled
  pins, chassis mount
ABS enclosure with battery
  compartment (OKW size # 3 for AA
  cells, e.g. RS Components # 583-
  218)
PCB, order code 030076-1 (see
  Readers Service page)
Disk, Windows software, order code
  030076-11 or Free Download
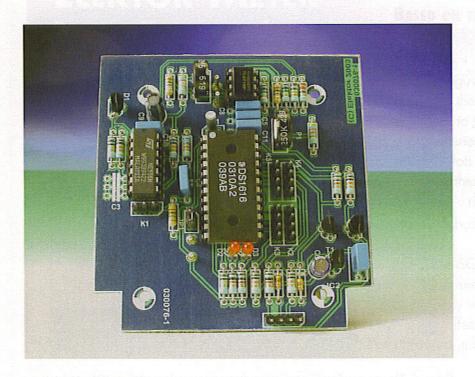
the window or by pressing the *Update* button.

Auto Scaling gives an overview of the series of temperature readings. The graph limits are no longer set at –40 °C and +80 °C, but are set to the lowest and highest temperature values stored in the data memory. The Save command stores the measured values on the local hard disk, with a user-selected path.

The Humidity, ADC1 and ADC3 plots are identical in terms of function and appearance. In future versions of the software the two spare channels will also be used.

Other Windows

The *ADC Channels* window can be called up under *ADC Channels/Show ADC Channels* in the main menu. It provides up-to-date readings from the analogue channels. Disabled inputs are displayed in grey, as shown on the right in **Figure 8**. Threshold values can also be set for the analogue inputs: these operate in the same way as the temperature thresholds.

The *Alarm Settings* window (**Figure 9**) includes the various settings relating to the RTC (real-time clock).

The RTC can be set to the PC's system time using *Set*. The remaining settings can be used, for example, to implement a time switch function. An interrupt on INT is generated when the RTC value agrees with the preset alarm time. RTC and alarm settings can only be changed while the DS1616 is not busy taking a sequence of readings.

Under *Settings/Performance* is a facility for setting to any desired value the timer period which governs the regular reading of data from all the sensors and analogue inputs. The greater this value, the greater the interval between samples, and the correspondingly smaller the amount of CPU time consumed by the software. An optimum value for the timer period can be found using the *System Monitor* (a Win XP utility) to accurately measure the CPU load and performance. PCs and laptops that have plenty of memory and processor power should have no problem with a timer interval of one second. The functions of the *System Monitor* are described in more detail in the help.

Operation

The climate logger is connected to a free serial port on the PC or notebook using an ordinary serial cable (straight-through, **not** a null-modem cable). The first time the logger software is run the selected COM port must be specified; this setting is stored and need not

Temperature Thresholds

These threshold values set the temperature limits above or below which the alarm flag in the Status 1 register will be set, which in turn pulls the interrupt output INT low. This latter signal is available on K2 and K3 and can be used, for example, to trigger an acoustic warning signal. The 'Clear' button must be pressed to reset the alarm flag.

Temperature and Other Graphs

This window provides information about the measured temperature values (**Figure 7**). Sample 1 corresponds to the time given under *Mission started @*. This allows the date and time of each stored sample to be determined. In order not to waste CPU time needlessly, an automatic update feature is not provided. The graph can be updated by re-opening

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Calculating the battery life

The type CR1620 backup battery (3 V, 60 mAh) supplies only the DS1616 and its internal temperature sensor. The humidity measurement circuit consumes rather more current and so is supplied from two AA cells to give a reasonable battery life. The life of the coin cell depends on the selected sample rate; in order to calculate the battery life, its capacity must simply be divided by the average current consumption of the circuit (I_{avg}).For example, with a sample period of 60 s we have:

$$\text{Battery life} = \text{battery capacity} / I_{avg}$$

where the average current is given by

$$I_{avg} = [t_{tc} \cdot i_{tc} + (T - t_{tc}) \cdot i_{OSC}] / T$$

where t_{TC} is the duration of one measurement (150 ms), i_{TC} is the current drawn while carrying out a temperature measurement (0.5 mA), i_{OSC} is the quiescent current consumption (450 nA), and T is the sample period (60 s).

The calculated battery life is approximately four years.
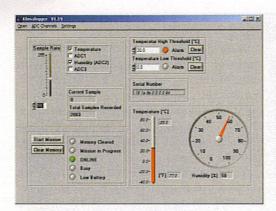
Figure 6. All the important parameters are shown in the main window.

Figure 7. The series of measured values (temperature, humidity, or either of the two spare inputs) can be displayed as a graph or as a table.

be entered again unless the logger is connected to a different COM port.

When first powered up a new DS1616 has its RAM filled with 0xFFs. When the climate logger is connected to the PC for the first time, the RTC time and a (sensible) sample rate must be set. This must also be done whenever the device's backup battery voltage is interrupted (i.e., when BT2 is changed). Until the sample rate is set, the PC will read a measured value every second, and the display will be updated every second.

While the data logger is connected to the PC, the sample rate and other parameters
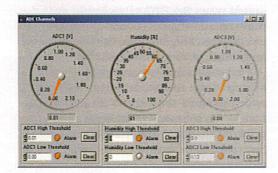
Figure 8. The three external analogue inputs are shown under *ADC Channels*.
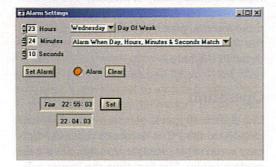
Figure 9. Using the alarm settings the Climate Logger can be used as a time switch.

can be set and adjusted as desired for the next mission. When the data logger is disconnected from the PC it retains these settings and operates in standalone mode. The settings will only be lost if the backup battery supply to the DS1616 is interrupted.

In the most recent version of the software available as we went to press (v1.23), a mission can also be initiated using the pushbutton connected across JP1. This is done as follows. First configure the sample rate, enabled channels and so on as described under 'Software' above. Then click on 'Enable External Start' and clear the memory contents: the 'Memory Cleared' indicator will appear on the screen. The logger can now be disconnected from the PC and taken to the location where measurements are to be made. To initiate the mission, it is now simply necessary to press the pushbutton for at least 0.5 seconds; data recording will then begin.

Measurements can also be initiated using the pushbutton while the logger is still connected to the PC. It is not necessary to shut down the program: it can remain running and will check whether a mission has been initiated.

If any of the settings (enabled channels or sampling rate) is changed after 'Enable External Start' has been clicked, the 'Enable External Start' feature is automatically reset. 'Enable External Start' should only therefore be clicked when all the needed settings have been configured, since it is at this point that the selected sample rate and channel selections are transferred to the DS1616. If any settings are subsequently changed on the PC, they will not be sent to the DS1616, and so the configuration of the logger will not match what is displayed on the screen.

(030076-1)

ELEKTOR-METER
PRECISION MEASUREMENT CENTRAL

ELEKTOR HARDWARE & SOFTWARE

BASED ON THE MSC1210 DEVELOPMENT SYSTEM

In the July/August 2003 issue we started a series of articles based on the Texas Instruments MSC1210 microcontroller. Thanks to this contemporary controller and its 24-bits A-D converter, the development system can be programmed for lots of applications and measurement functions. Among these is a high-accuracy digital meter with no less than 5½ digits and 8 analogue inputs. All you have to do to build the instrument is add an LCD!

Because the MSC1210 microcontroller comes in an SMD case with 0.5-mm (0.02 in.) pin spacing, soldering the device properly with DIY tools is almost impossible. That's why we are offering the development board as a ready-manufactured unit only.

Gameboy
Digital Sampling Oscilloscope

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The GBDSO (Gameboy Digital Sampling Oscilloscope), published in Elektor Electronics October and November 2000 is still in great demand.

The GBDSO is a plug-in module that turns the popular Nintendo Gameboy Classic, Colour or Advanced into a versatile dual-channel oscilloscope. An optional link to a PC even allows measured oscillograms to be viewed or stored on the PC. The GBDSO comes as a ready-built and tested PCB and may be ordered via our website: *www.elektor-electronics.co.uk*

The ready built GBDSO board costs *£ 90.00 including the associated PC software and the magazine articles* (published in the October and November 2000 issues).

Order now on *www.elektor-electronics.co.uk*

FMS Flight Simulator Encoder

Practice without crashing your models

By Dean Sarelius   d.sarelius@bigpond.com

We all know that even the best pilots spend many hours practising on flight simulators before taking to the real thing, so why should it be any different for radio control planes? With the FMS R/C Flight Encoder described here you can polish your flying skills and gain the valuable experience you need without having to invest in a radio control or even to build a model airplane. In fact the FMS encoder will even allow you to use your own radio control to further enhance your flying ability.

Last year the author purchased a JR 4-channel radio control (R/C) and built his first electric powered plane. Unfortunately the maiden flight was a disaster so a more serious look at flight simulators was in order. Unfortunately, the cost of the so called professional simulators was too much to justify. Searching the Internet, a website called FMS was found.

FMS (Flying Model Simulator) is a freeware 3D flight simulator program developed and written by Roman & Michael Möller. FMS has been compiled to run in both DOS and Windows and with thanks to Roman and Michael it is available as a free download from their website http://n.ethz.ch/student/mmoeller/fms/index_e.html.

The FMS simulator provides control of planes and helicopters either by keyboard, joystick, parallel port or the serial port. The keyboard and joystick options are fine but if you wish to practice flying planes with your own radio control it is necessary to use an adapter which converts the 'buddy' signal from the radio into data to interface to the computer. More about this further on.

A brief history

In the 1960's two engineers, Doug Spreng and Don Mathers of NASA, developed the original digital proportional control system and a standard was set for the type of pulses required to control servos in radio control applications. With the Mathers and Spreng pulse position modulation system (or PPM) pulses are transmitted — five pulses for a 4-channel, six for a 5-channel and so on. It is the space between these pulses which determines the position for the servos. These pulses are modulated such that the position between them is allowed to vary between 1 ms and 2 ms. For a 1.5-ms delay between pulses the servo would remain at centre, while anything less than 1.5 ms would force the servo to turn anti-clockwise and anything above would make it turn clockwise. The greater the time delay positive or negative from 1.5 ms the further the rotation of the servo. When the encoder is used to interface to your radio control, it is the time delay between these pulses which is converted into numerical form to interface to the computer.

There are a number of different ways to obtain the PPM signals from your R/C radio and this will depend on which radio you have. More about this later.

So how does the encoder work?

The encoder can work 'stand alone', without any need for a radio control. In this mode you simply plug it into the serial port of your computer and use both joysticks as you would a normal R/C.

In the second mode of operation you will need the PPM signal from your radio. Once you have connected this signal you only need to press down on the joystick (actuating the internal switch) to toggle the mode so that the PPM signal from your radio control is used to interface to the simulator. In this mode you use the encoder to decode the PPM signals
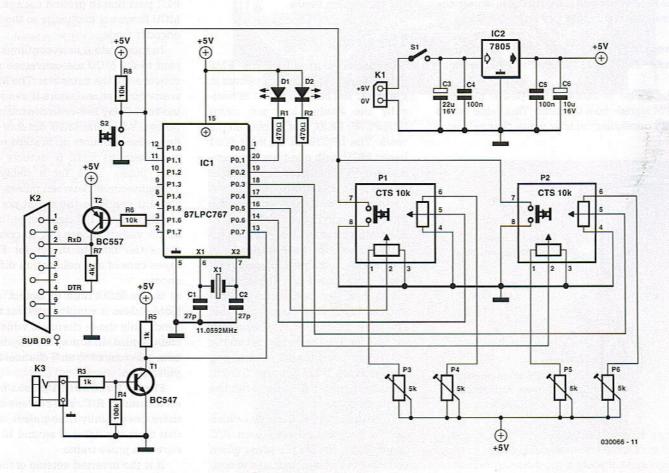
Figure 1. Circuit diagram of the FMS Encoder. All intelligence is vested in microcontroller IC1. Connector K3 allows you to connect your own R/C transmitter unit via its 'buddy/trainer' outlet.

from the radio and convert them into serial data for the computer. You are now using your own radio control to fly the virtual models, so with practice you gain confidence flying with your own R/C.

Within FMS options for 'Control' you will find the 'Serial PIC-interface'. You can choose from two options, but it is the 19200 Baud / 0xFF Sync which this design is set to run with. Make sure to select the correct COM port and set it up in the following way:

– 19200 baud
– 8 bit data, 1 stop bit, no parity
– RTS set to HI
– DTR set to LOW

With the FMS encoder plugged in and the correct COM port set up and calibrated you are ready to start flying.

The encoder sends one packet for all channels. Every packet starts with 0xFF and a byte is added with a value between 0 and 254 (0x00 to 0xFE hex) which provides the information for the servo position. Since 0 to 254 values are available for a range of 1 ms to 2 ms, the value which equates to 1.5 ms or centre position is 127 (0x7F hex).

So for a 4-channel R/C with all servos in the neutral position the data being sent to the computer would look like this:

Pause *0xFF 0x7F 0x7F 0x7F 0x7F* **Pause** *0xFF 0x7F 0x7F 0x7F 0x7F* **Pause** etc.

The pause is actually the pause between PPM signals from the radio. This value would vary depending on how many channels your
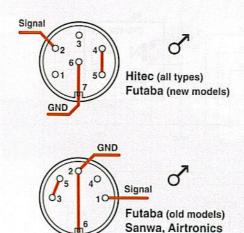
Figure 2. Pulses captured from an 8-channel R/C.
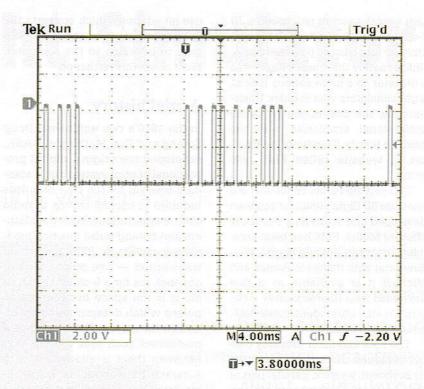
R/C generates — the more channels, the shorter the pause.

The circuit

The circuit diagram of the FMS Flight Simulator Encoder appears in **Figure 1**. You can see that it is basically the Philips low pin count P87LPC767 MCU, that's doing all the work. The LPC767 is an 8-bit 8051 based MCU with one-time programmable (OTP) PROM and four (!) channels of 8-bit analogue to digital converters. A programmer for the LPC76x family was described in *Elektor Electronics* December 2003.

At power-up the encoder is in **SIM mode**, reading the joystick positions from the four 10-kΩ linear potentiometers contained in joysticks P1, P2, then converting this analogue information into packets of data to send to the serial port on the PC. To provide a means of trimming the controls, 5-kΩ presets (P3-P6) have been added in series with the joysticks pots.

To engage the **R/C mode** (which allows you to use your own R/C transmitter) you simply press down on either of the two joysticks to activate an internal tactile switch. If the joysticks are not fitted, the same is

achieved by pressing S2. Pulling the P1.1 port line to ground causes the MCU firmware to change to the R/C encoder mode.

In this mode pulses continuously sent to the MCU are converted and conveyed to the computer. The MCU waits for a pause before it samples the time delay between consecutive pulses. After the MCU detects the first pulse, it counts up in steps of 10 microseconds until it detects the next pulse. Thus for a delay of 1.5 milliseconds between pulses, the value it sends to the serial port is approximately 127 decimal or 0x7F. Minor variations are not so critical since the built-in driver for FMS takes care of any calibration differences.

If the MCU fails to detect any more pulses it simply bails out and sends only those channels which it could count, this may be anything from a 2-channel to an 8-channel R/C pulse train.

Figure 2 shows the pulses from an 8-channel R/C. You can see that there are actually nine pulses, and that there is a delay of around 10 ms between pulse trains.

It is the inverted version of these pulses which are sent to buffer transistor T1. These pulses are inverted

Figure 3. Signal functions on the buddy/trainer socket of some commonly used R/C transmitters. If yours is not shown, consult the owners manual or ask help from fellow FMS users via the FMS Forum.

COMPONENTS LIST

Resistors:
R1,R2 = 470Ω
R3,R5 = 1kΩ
R4 = 100kΩ
R6,R8 = 10kΩ
R7 = 4kΩ7
P1,P2 = mini joystick, CTS model
   25A104A60TB (order code
   CTS25A from www.dil.nl)*
P3-P6 = 5kΩ preset

Capacitors:
C1,C2 = 27pF
C3 = 22µF 16V axial
C4,C5 = 100nF
C6 = 10µF 16V axial

Semiconductors:
D1 = LED, green, 3mm
D2 = LED, red, 3mm
IC1 = 87LPC767BN,
   programmed, order code
   030066-41
IC2 = 7805CP
T1 = BC547B
T2 = BC557B

Miscellaneous:
K1 = 9-V battery with clip-on
   leads
K2 = 9-way sub-D socket
   (female), PCB mount
K3 = 3.5mm mono jack socket,
   chassis mount
S1 = on/off switch
S2 = pushbutton, 1 make contact
X1 = 11.0952MHz quartz crystal
PCB, order code **030066-1**
3 wire links
RS-232 cable (non-crossed)
Case, e.g., Pactec WM-46 (Conrad
   Electronics # 54 13 03)
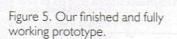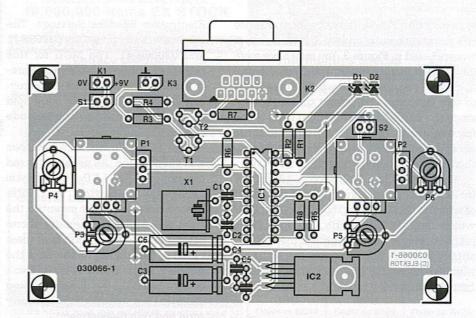
   * Worldwide distributor
   information from
   www.ctscorp.com

Figure 4. Copper track layout and component mounting plan of the PCB designed for the FMS Encoder (board available ready-made).

by T1 thus bringing them back to normal before they are sent to MCU pin13.

Output data from MCU port line P1.6 (pin 3) is buffered by T2, with R7 providing the required level shifting to drive the RS232 port.

Only two wires are required from your R/C radio to interface to the

Figure 5. Our finished and fully working prototype.

FMS encoder. Where these connections are will depend on what type of R/C you have. A few are listed in **Figure 3**. You may have more information available from your radio control manual. If you are unsure which connections to use then don't be afraid to experiment since the buffered input is quite safe. If you fail to place them the right way around the encoder will behave erratically — just swap them over and everything should be okay.

The whole circuit runs off a single 9-V (6F22) battery and draws only 21 mA, most of which is consumed by the LEDs D1 and D2 which indicate SIM mode and R/C mode respectively. A 7805 regulates the battery supply down to 5 V to power the MCU. At least five hours play time should be available from a standard 9-V battery.

Construction

Construction of the FMS Flight Simulator Encoder board should be easy if you use a ready-made printed circuit board and a programmed MCU supplied through the *Elektor*

Electronics Readers Services. The respective order codes are **030066-11** and **030066-41**. The MCU for this project is only available ready-programmed. The author receives royalty payments for every copy sold hence no hex code or source code files can be supplied.

The PCB (**Figure 4**) is spacious and single-sided. As usual, polarized components like LEDs, electrolytic capacitors, transistors and integrated circuits should mounted the right way around on penalty of creating a hard to find circuit fault (best case) or destroying them when the power is applied (worst case). Don't swap T1 and T2, the devices looking identical but being complementary (npn and pnp respectively).

The MCU being the most expensive component, it really deserves to be fitted in a good quality IC socket. However, it should not be inserted in the socket before you have verified

and approved the presence of the +5 volt supply voltage at a number of relevant points in the circuit, for example, IC1 socket pin 15, the emitter of T2 and the anode wires of LEDs D1 and D2. Okay so far? Then switch off and insert the MCU, observing the position of the notch on the PCB overlay.

Pinheader strips beside joysticks P1 and P2 are provided to connect joysticks that do not fit the board, or an old R/C of which the RF sections are faulty or even missing.

Finally

Users of the Encoder described in this article are encouraged to communicate with other FMS users via the Forum which can be accessed via the FMS homepage. Happy flying!

(030066—1)

RIAA Preamp
with FETs

SRPP equaliser for moving magnet (MM) cartridges

Design by H. Breitzke
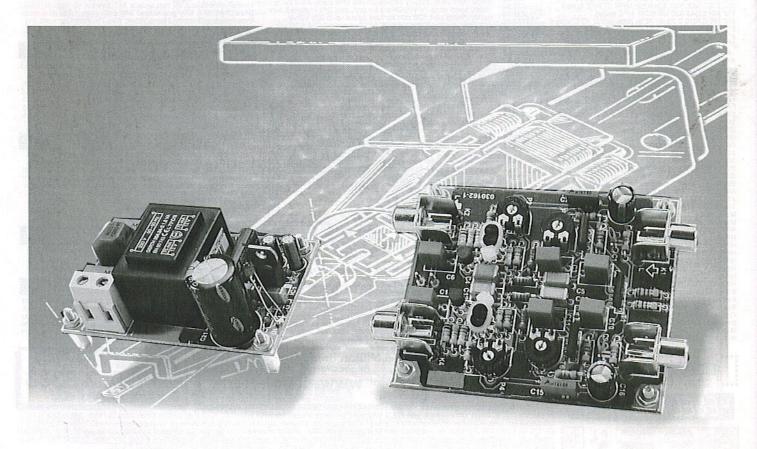
This preamplifier and equaliser is based around field effect transistors and is an updated version of the SRPP valve preamp we published in March and April 1987. Various changes are necessary due to the fact that the FET SRPP configuration offers a considerably higher gain and output impedance than its valve sibling.

The *Shunt Regulated Push-Pull* (SRPP) topology is frequently used in high-frequency applications, but is seldom seen in audio circuits. This is simply because SRPP works well with valve technology, but is not suitable for use with bipolar transistors or with operational amplifiers because the circuit does not employ negative feedback.

As a result distortion is considerably increased. Using FETs, however, we can employ the SRPP topology as effectively as with valves.
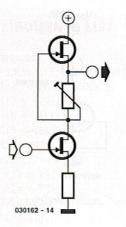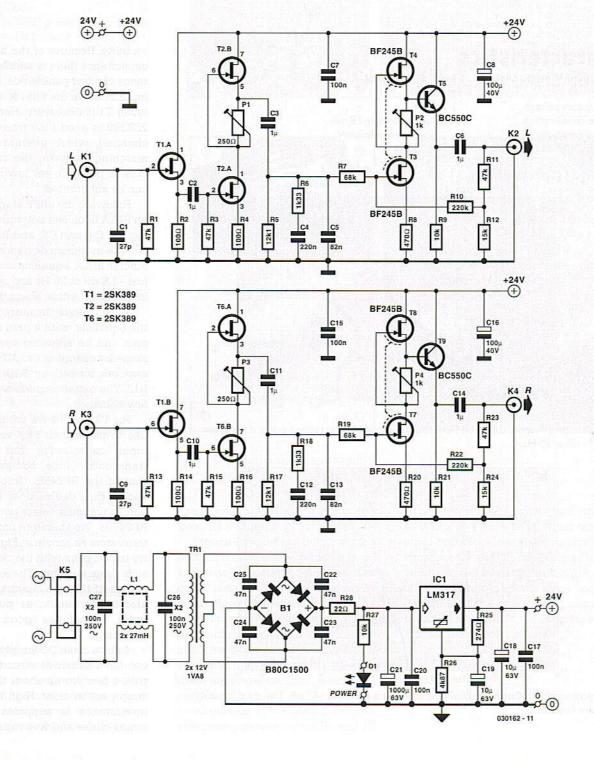
Figure 1. Push-pull circuit with SRPP topology.

SRPP

The SRPP technique is based on a push-pull arrangement (**Figure 1**), where the transistors or valves are, for the purposes of DC analysis, connected in series. The signal is taken to the gate of the lower FET. The AC voltage dropped across the impedance in the source connection of the upper FET serves as an out-of-phase drive voltage for the upper FET, since the drain of the lower FET is connected to the gate of the upper FET. Meanwhile, the DC voltage drop across the trimmer potentiometer provides the gate bias voltage for the upper FET. From the point of view of the

Figure 2. The circuit of the RIAA equaliser includes a high-quality power supply.

lower transistor the upper transistor appears as a current source, while the output is taken from the upper transistor in a source-follower arrangement. This special push-pull topology reduces the output impedance of the transistors by a factor of 3 or 4. The operation of the SRPP circuit is straightforward: it is surprising to discover, then, what advantages it offers both technically and in terms of how it sounds:

– very low distortion;
– extremely high linearity;
– high gain;
– generous headroom;
– low output impedance.

The Circuit

Aside from the power supply, the circuit in **Figure 2** consists of two identical amplifier stages: we will describe the left channel. Central to the amplifier is the SRPP arrangement around T2a and T2b, which has a gain of approximately 280. A type 2SK389 dual FET is used to reduce noise and to improve thermal
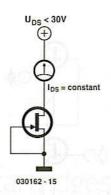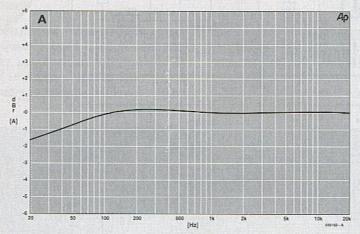
Figure 3. Circuit used for selecting FETs.
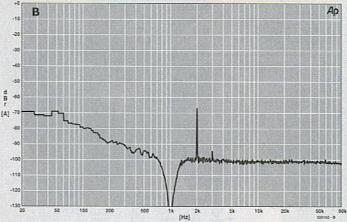
Characteristics

(with 200 mV output voltage, 1 kHz, 47 kΩ load)

Power supply voltage	24 V
Current consumption	approximately 18 mA
Nominal sensitivity	approximately 2 mV
THD+N (400 Hz to 22 kHz)	0.054 %
S/N	>71 dBA

Curve A shows that the deviation from the standard RIAA correction curve is very low: only –1.6 dB at 20 Hz.

The spectrum plot in **Curve B** shows the second harmonic at –67 dB. The third is barely above the noise floor.

stability. Because of the high input capacitance there is a Miller capacitance of a few nanofarads, and so an input buffer in the form of source-follower T1 is necessary. Here again a 2SK389 is used (one transistor per channel), which guarantees good matching between the two channels. In principle any low-noise FET can be substituted.

Following the SRPP stage there is an RIAA equaliser network comprising C3, C4, and C5, and R5, R6 and R7. The maximum deviation from the official RIAA equalisation curve is just –1.6 dB at 20 Hz and agreement is generally within about 0.3 dB.

T3 to T5 form the output stage of the equaliser, with a gain of 12. The gain can be adjusted over a wide range by changing the AC feedback network formed by R10, R11 and R12. The output impedance is just a few ohms.

For T3 and T4 we would ideally like to use a dual FET with a low input capacitance but with a transconductance comparable to that of the BF245B. Unfortunately such a dual device does not exist, and so we must select two suitable BF245Bs. We therefore connect the transistors as shown in **Figure 3** and try to find pairs with the closest possible drain currents. The lower transistors of the two channels should also be as similar as possible in order to achieve good channel matching.

Since a clean DC supply is essential for a sensitive circuit such as this, a few words about the power supply are in order. High-frequency interference is suppressed by a mains choke and two capacitors on

COMPONENTS LIST

Resistors:
R1,R3,R11,R13,R15,R23 = 47kΩ
R2,R4,R14,R16 = 100Ω
R5,R17 = 12kΩ1
R6,R18 = 1kΩ33
R7,R19 = 68kΩ
R8,R20 = 470Ω
R9,R21,R27 = 10kΩ
R10,R22 = 220kΩ
R12,R24 = 15kΩ
R25 = 274Ω
R26 = 4kΩ87
R28 = 22Ω
P1,P3 = 250Ω preset
P2,P4 = 1kΩ preset

Capacitors:
C1,C9 = 27pF
C2,C3,C6,C10,C11,C14 = 1µF
  MKT, lead pitch 7.5mm
C4,C12 = 220nF
C5,C13 = 82nF
C7,C15,C17,C20 = 100nF
C8,C16 = 100µF 40V radial
C18,C19 = 10µF 63V radial
C21 = 1000µF 63V radial
C22-C25 = 47nF ceramic, lead
  pitch 5mm
C26,C27 = 100nF 250 VAC (Class
  X2), lead pitch 15mm

Inductors:
L1 = suppressor choke 2 x 27mH
  (Epcos # B82721-K2401-N21)

Semiconductors:
B1 = B80C1500 bridge rectifier,
  rectangular case (80V piv, 1.5 A)
D1 = LED, low current
T1,T2,T6 = 2SK389-BL (Toshiba),
  (www.reichelt.de)
T3,T4,T7,T8 = BF245B (see text)
T5,T9 = BC550C
IC1 = LM317 (TO220 case)

Miscellaneous:
K1-K4 = cinch socket, PCB mount
  (Monacor/Monarch # T-709G)
K5 = 2-way PCB terminal block,
  lead pitch 7.5m
TR1 = mains transformer, 2 x 12V
  / 1.8VA (e.g. Gerth # 304.24-2)
PCB, available from The PCBShop.
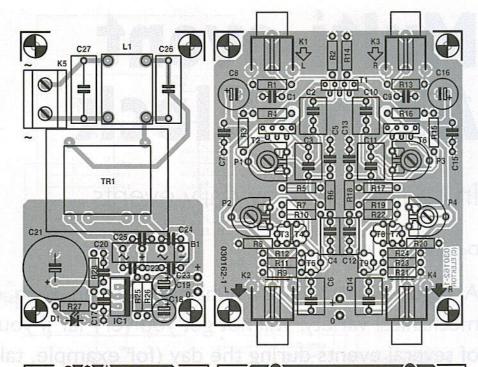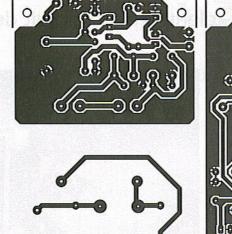
Figure 4. Printed circuit board layout.

the primary side of the small 24 V transformer. On the secondary side capacitors are connected across the diodes in the rectifier bridge, which suppress interference caused when the diodes switch. The LM317 volt-age regulator produces a stable and clean 24 V supply.

Figure 4 shows the layout for the printed circuit board, which has an extensive ground plane. Unless the board is to be mounted as a whole inside the enclosure, the power supply section should be cut off before populating the board. The layout and the component arrangement are practically symmetrical, and there are two wire links, near to K2 and K4.

Alignment of the circuit involves adjusting potentiometers P1 and P2 so that the voltages at the source connections of T2b and T4 are each equal to $U_b/2$. The input capacitance of the circuit is formed by capacitor C1 and the input capacitance of T1, which, in the case of the 2SK389, is around 20 pF. The optimum input capacitance depends on the type of cartridge, and will normally be found in the specifications of the system.

(030162-1)

Internet address:
www.tubecad.com/may2000/

Multi-event Alarm Clock

In control of many daily events

Design by K.-U. Mrkor
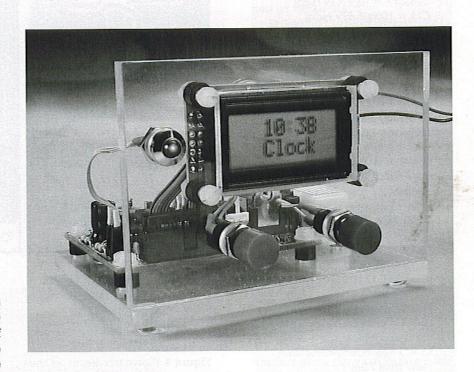
A regular alarm clock, whether stuffed with electronics or of the mechanical variety, will not get you very far if you need to be reminded of several events during the day (for example, taking your medication). What you need is a multi-talent like the circuit described here.

The circuit diagram of the Multi-event Alarm Clock shown in **Figure 1** is easy to understand, the central parts being a contemporary combination of a microcontroller, a real-time clock and an LC display. At the heart of the circuit sits a powerful yet inexpensive and widely available 8051-compatible 8-bit microcontroller type AT89C2051 from Atmel. Its main features may be summarized as follows:

– full 8051 software compatibility;
– 2 kbytes of Flash memory;
– integrated analogue comparator;
– multiple outputs with LED drive capability;
– static architecture (0-24 MHz)
– extended supply voltage range (2.7-6 V).

Quite important for this application, the chip comes in a small enclosure with 'just' 20 I/O pins. Port 1 and Port 3 (with the exception of the P3.6 line) provide 15 freely programmable port lines. This should be more than adequate to connect the following peripherals: an LCD to display time and menus, two pushbuttons to set the clock and the alarm times, an LED and a piezo buzzer as an acoustic alarm.

To these elements should be added a real-time clock (RTC) component type DS1307 which communicates with the MCU via an I^{2}C link. Thanks to a 3-volt Lithium backup battery, the DS1307 will keep 'ticking' in the absence of the supply voltage. Suitably programmed, the chip supplies a seconds pulse at the SQW/OUT pin.

Clock reference adjustment

In real life, the clock output of the DS1370 will rarely supply a pulse with a period of exactly 1.000000 seconds. This is because the quartz crystal used in the RTC clock oscillator circuit is subject to a certain production tolerance. The author purchased and tested a number of these quartz crystals and found pulse periods of up to 1.000008 seconds at the chip output. Unfortunately, what appears to be a totally harmless error in the sixth decimal position can well be the cause of serious degradation in the clock's final accuracy, amounting to an error of four minutes per year.

Although the error may be compensated by adjusting trimmer C5,

that really makes sense only if you have a reliably and extremely well calibrated frequency counter boasting a microseconds range. Assuming you have such an instrument (or have access to it) then the probe may be connected to pin 7 of the DS1307 and the trimmer adjusted for a reading that's acceptable. Failing the above, C5 is best omitted from the circuit.

Power supply

The power supply for the circuit is of a less conventional design, consisting of a low-drop voltage regulator, IC3, with its usual satellite parts. Its function is to turn the external supply voltage (from a battery or a mains adapter) into a stable 5-V supply rail for all circuit parts except the LCD backlight. Jumper JP1 ensures that the backlight current is never drawn from a battery — after all, we're looking at something between 40 and 240 mA depending on the LCD type you decide to use. The current circuit around T2-T3-T4 (actually a current mirror) only works when a mains adapter is used to power the circuit, supplying the necessary current for the backlight lamp(s).

The current consumption of the circuit with the exception of the LCD amounts to just 5 mA which may be lowered even further by a small reduction in the MCU clock frequency. The MCU itself does not execute time-critical tasks and will happily run at a clock frequency as low as 2.4576 MHz. The only consequence of a relatively low MCU clock frequency (determined by the quartz crystal) is a slightly sluggish menu when the clock and alarm times have to be set.

Obviously the DS1307 is not affected by these changes because it employs its own timebase.

Software

The software for the project was written in the 'C' higher language, using Keil's µVusion2 package as a development platform of which a free evaluation version may be downloaded from

www.keil.com/demo/eval/c51.htm
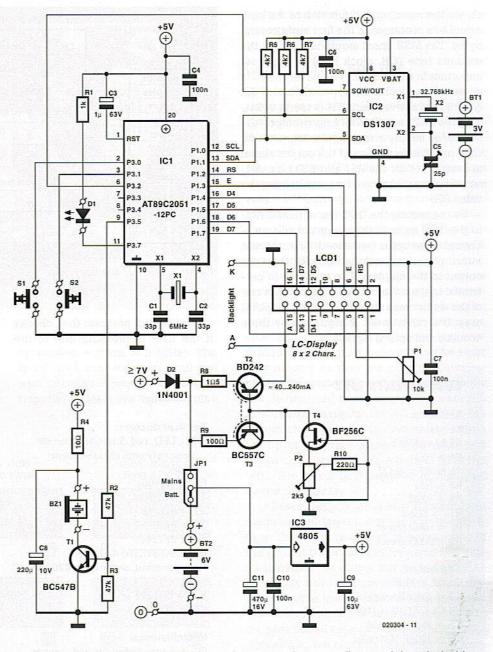
Figure 1. The main components in the project are a microcontroller, a real-time clock chip, an LCD and two pushbuttons.

The only limitations of this version are (1) non-commercial use and (2) a maximum object code size of 2 kbytes. The latter limitation is hard to object to if you realize that the size of the AT89C2051 Flash memory is also 2 kbytes!

The microcontroller executable code looks after several tasks including outputting the current time, communicating with the user via a menu structure and, last but not least, enabling the acoustic actuator when an alarm time is reached.

The seconds clock pulse that's crucial to the function of the Multi-event Alarm Clock is generated by the DS1307 and fed to the AT89C2051 MCU by way of an I2C bus interface. Unlike some other 8051 derivates from Philips, the AT89C2051 does not have an on-chip I2C interface, hence a few I2C routines had to be written based on an example supplied by Keil.

Access to the real-time clock is similar to reading/writing a memory device. The only point to keep in mind is that the first eight bytes in the RTC RAM are reserved for the clock itself. The battery backup makes the remaining 56 free memory locations ideal for the storage of alarm times. However, the DS1307 has to be initialised before it can be used as a timebase. The initialisation comprises adjusting the clock and loading the control bytes. The memory map in **Figure 2**

shows the meaning and function of the individual bits contained in the first eight control bytes. The MSB (most significant bit) in the seconds byte (CH, clock halt) is the most important in this respect. Whenever the IC is powered up, this bit always reads 1, and the clock is not started until CH is made 0. Setting the OUT and SQWE bits prompts the DS1307 to supply a rectangular signal at its OUT pin. The frequency of the output signal is determined by the RS1 and RS0 bits. A 1-second pulse is obtained by programming the value 00b.

By connecting the OUT line of the DS1307 to the $\overline{INT0}$ input of the microcontroller, a 1-second interrupt is generated. The relevant interrupt service routine updates the time output to the display. Next, a check is performed to see if the current time matches one of the alarm times stored in the DS1307 RAM area. If so, that event is signalled by three acoustic and optical signals.
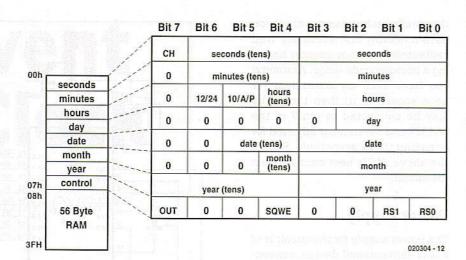
Figure 2. DS1307 memory map.

The control program then checks if the user is pressing one of the pushbuttons to call up the menu. If so, the menu is made available, else,

COMPONENTS LIST

Resistors:
R1 = 1kΩ
R2,R3 = 47kΩ
R4 = 10Ω
R5,R6,R7 = 4kΩ7
R8 = 1Ω5
R9 = 100Ω
R10 = 220Ω
P1 = 10kΩ preset
P2 = 2kΩ5 preset

Capacitors:
C1,C2 = 33pF
C3 = 1µF/63V radial
C4,C6,C7,C10 = 100nF
C5 = 25pF (trimmer)
C8 = 220µF 10V radial
C9 = 10µF 63V radial
C11 = 470µF 16V radial

Semiconductors:
D1 = LED, red, 5mm, low current (optionally with chassis-mount holder)
D2 = 1N4001
T1 = BC547B
T2 = BD242
T3 = BC557C
T4 = BF256C
IC1 = AT89C2051-12PC, programmed, order code 020304-41
IC2 = DS1307
IC3 = 4805

Miscellaneous:
JP1 = 3-way pinheader with jumper
S1,S2 = pushbutton, 1 make contact, chassis mount
LCD1 = LC display, 16 characters (2 lines x 8), e.g. AV0820 from Anag Vision) plus 16-way boxheader
X1 = 6MHz quartz crystal (parallel resonance)
X2 = 32.768 kHz quartz crystal
BT1 = 3V Lithium cell type CR2032 with PCB mount holder (22.75mm diam.)
BT2 = see text
BZ1 = 5V or 6V DC buzzer (active piezo)
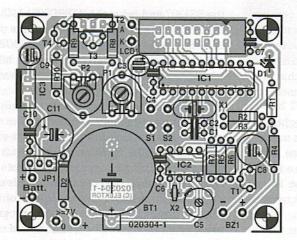
PCB, available from **The PCB Shop**

Disk, microcontroller C (source) and hex files, order code 020304-11 or Free Download
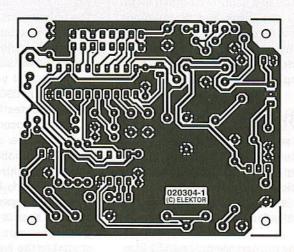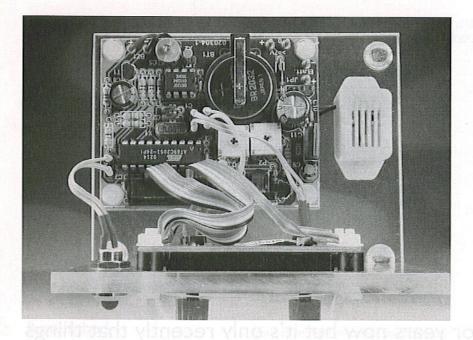
Figure 3. Copper track layout and component mounting plan of the PCB designed for the Multi-event Alarm Clock.

the microcontroller changes to 'sleep' mode. In this energy-saving mode, the AT89C2051 consumes just 1.6 mA as opposed to 7.5 mA

(assuming a clock of 6 MHz). The MCU does not wake up until the next interrupt is request is received from the DS1307, when the display

update and pushbutton check routines are run again.

Construction and use

The circuit is conveniently built on the single-sided printed circuit board of which the layout is shown in **Figure 3**. It should be noted that a number of components are not accommodated on the board — these include the 'large' battery, BT2 (which may take the form of two Lithium cells, four Alkaline cells or a single 9-V battery), piezo buzzer BZ1, pushbuttons S1 and S2 and, of course, the LC display. The latter is connected by way of a 16-way pinheader and two extra solder pins (A and K for the backlight).

Populating the board should not cause problems as there are no unusual components to deal with or special mounting methods to observe. As a matter of course, electrolytic capacitors, transistors and integrated circuits must be mounted the right way around as they are polarized components. Transistor T2 and voltage regulator IC3 do not need heatsinks as they pass relatively low currents. As illustrated in the introductory picture, the two pushbuttons are fitted directly onto the case panel, just below the display (S1 to the right, S2 to the left). The alarm LED may also be mounted below the display.

All user settings are guided by the in-built menu and entered using the two pushbuttons. The menu is entered by keeping one of the pushbuttons pressed for about one second. Within the menu, the items to define invariably have two options, which are displayed in the lower of the two display lines. The desired option is selected by pressing the pushbutton below the relevant text on the display (i.e., left or right).The three main functions, clock adjust, alarm adjust and alarm clear, are shown pictorially in **Figure 4**.

(020304-1)

Web pointer
DS1307 datasheet at
http://pdfserv.maxim-ic.com/en/ds/DS1307.pdf

Figure 4. Operating the clock could not be easier using the built-in menu.

The content of this note is based on information received from manufacturers in the electrical and electronics industries or their representatives and does not imply practical experience by Elektor Electronics or its consultants.

HV9901

A novel LED driver

By E. Haug

LEDs have been around for years now but it's only recently that things have started to get interesting with white and superbright versions appearing at reasonable cost. LEDs of course require some form of driving circuit and there is a lot of interest in more efficient or versatile techniques for driving them. This circuit isn't fussy; it outputs a constant current suitable for high power LEDs and it doesn't care whether the input is 12 V or 230 V!

It sometimes happens that a chip manufacturer comes up with an IC to perform a specific function and later the chip is found to be useful in a different application, not anticipated by the original designer. The HV9901 Universal Relay Driver from Supertex Inc. is just such a device. It was originally designed to provide a constant current output drive for a relay coil from a very wide range of supply voltages from 10 V up to 450 V DC without the need to alter any of the circuit components. This device offers a number of benefits both to the designers of white goods where the variety of relays used in equipment can be reduced (optimising quantity discounts) and also to the maintenance engineer who does not need to check coil ratings of a replacement relay. The HV9901 operates at DC voltages only so for AC operation a bridge rectifier is also needed (but no reservoir capacitor is usually necessary).

How come that LEDs and relays are so alike that they can both be driven by the same chip? Well both require the drive current to be as constant as possible irrespec-
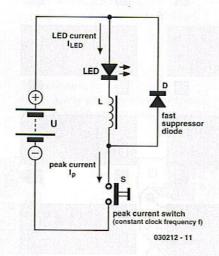
Figure 1. The switched current source configuration.

Figure 2. Internal diagram of the HV9901.

tive of the level of supply voltage. In the past with low current LEDs taking only a couple of milliamps the problem of driver design was not so great but with today's high power

devices consuming a few hundred milliamps up to 1 A the need for efficient drivers is more acute to avoid excessive dissipation in the driver circuit.
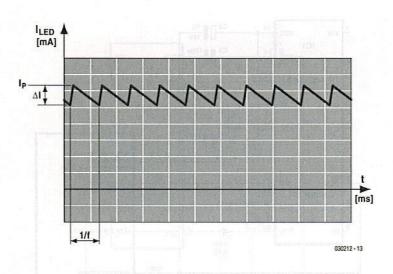
Figure 3. Load current waveform.

A switched current source

The step-down generator used in the HV9901 is a switched current source. **Figure 1** shows the principle of the circuit. When the switch is closed current through the coil begins to rise. The rate of current rise depends on the value of supply voltage and the coil inductance. Before current in the circuit rises too much the switch is opened and the flow is interrupted. The 'flywheel' diode allows current to continue to flow through

the coil and back to the positive supply but it decays almost linearly because of the energy losses through the coil and LED. Once more the switch is closed and current increases again until it is interrupted. This process is continually repeated so that current through the load has a ripple characteristic. The faster the switching process repeats, the smaller the peaks and troughs of the ripple will be. The HV9901 shown in **Figure 2** generates the PWM signals to switch the high voltage input through an external power

MOSFET to the load and measures the load current through a sense resistor to produce a (rippled) constant current output. The oscillator frequency is set by the value of resistance connected from the RT input to ground.

The ripple current ΔI (**Figure 3**) is governed by the coil inductance, clock frequency f and the peak LED current I_S. It is important to accurately control current through the LED because the maximum peak current of high current LEDs is only slightly more than their continuous current rating so it is important to achieve high brightness from the LED without over-driving it. Each time the peak value is exceeded the stress causes brightness reduction, colour change and can lead to the untimely death of the LED.

The ReLED driver

The circuit is capable of driving both relays (also electro mechanical valves and solenoids etc.) and all types of LED so the circuit was given the name ReLED (well it seemed like a good idea at the time). The circuit controls its output current by measuring peak current through the coil via a sense resistor and switching the supply on and off. This is not the conventional method of providing a constant current source but the circuit is very simple to use and performs reliably.

The HV9901 can accept input voltages in the range from 10 V to 450 V DC (providing that suitable MOSFETs and diodes are used) and not just 'pure' DC but also pulsed sup-
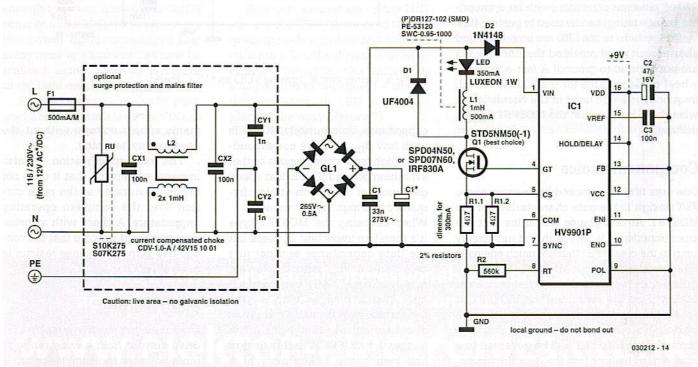
Figure 4. Circuit of the ReLED driver including the mains filter.

plies like unsmoothed rectified 50 Hz mains supply. This feature allows a high current output supply to be produced without the need for expensive and bulky electrolytic reservoir capacitors.

The circuit in **Figure 4** provides an output current of around 300 mA and is suitable to drive a blue or white 1 W Luxeon LED. Overvoltage protection and a mains filter is included on the input to the circuit to comply with EMC recommendations for any mains powered clocked circuit. Other types of LED can also be driven from this circuit providing that the value of the current sense resistors (R1.1 and R1.2) are changed if the LED current rating is different. The current sensing resistor should be of a type having low parasitic inductance, connecting two identical resistors in parallel helps to reduce any inductance and also shares the energy dissipation.

The coil inductance and the oscillator PWM switching frequency both play an important role in keeping the current ripple to an acceptable level.
In contrast to linear current regulators the value of input voltage has only a small effect on the power dissipation in the driver (and the efficiency of the circuit). Several individual LEDs can be connected in series and driven from this circuit provided there is sufficient supply voltage available. The minimum supply voltage required to drive an LED is 12 V DC or AC but with a rectified AC supply of less than around 30 V the period that the circuit cannot conduct around the zero crossing points of the rectified AC waveform is relatively long so the LED will noticeably flicker. A 220 µF reservoir capacitor (with an appropriate voltage rating) can be used to prevent this.

Connections to the LED are both open and short circuit proof provided that these leads are not shorted to ground! A fast-acting flywheel diode suitable for the 50 KHz switch frequency must be used in the circuit otherwise there is a risk that the MOSFET will be destroyed.

Component choice

One area often overlooked by newcomers to FET design is the gate characteristic of the MOSFET. At first glance we notice that the input impedance is very high and mistakenly jump to the conclusion that not much energy is necessary to switch the MOSFET. This is true if the device is operated at low frequencies or DC but if we are switching the MOSFET at speed another factor is important: the gate capacitance. The maximum switching frequency of the MOSFET will be governed to a large extent by how fast the gate driving circuit can charge and discharge this input
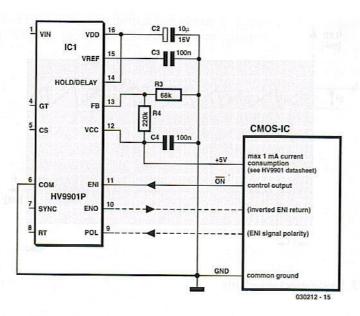
Figure 5. Auxiliary power for additional CMOS circuits.
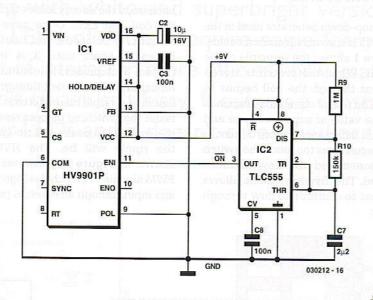
Figure 6. Flasher circuit showing VDD and VCC linked.

capacitance. Unfortunately MOSFETs with low $R_{DS(ON)}$ have correspondingly high input capacitances so that switching power MOSFETs at speed gets more of a problem at high frequency and high supply voltages.
When choosing the MOSFET type it's therefore important to check out the gate capacitance and not just select the device with the lowest $R_{DS(ON)}$. The HV9901 can comfortably switch devices with a gate capacitance up to 500 pF and can also cope with 1 nF at a push. The suggested MOSFETs in this design can switch the LED supply at a PWM frequency of 50 kHz from

mains supply voltage without the need for any heat sink.

The coil specification is also important to ensure that it does not become saturated at the peak current over the complete operating temperature. A check with an oscilloscope should indicate that the voltage rise across the sense resistor is more or less linear.

More features

In addition to providing a stable LED drive current from a wide range of input voltages the circuit also has a number of other features that may be
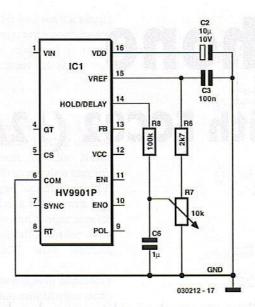
Figure 7. Simple dimmer control.

a step-up regulator by placing the load (e.g. a 12 V LED cluster) in series with the flywheel diode. In this mode the supply has a much higher ripple current.

Testing times

Before you try the circuit out with an expensive Luxeon LED it is a good idea to substitute a power zener diode instead of the LED. A zener diode has almost identical electrical characteristics providing you choose one with the same conduction voltage as the LED. The zener diode is a little more robust that the LED and any errors during testing will be far less costly. Connect a standard red LED together with a 180 Ω series resistor in parallel with the zener diode so that you can get a visual indication that the circuit is driving the LED with equal brightness at different input voltages.

All tests must be carried out initially using a low voltage (12 V) input. If the circuit is powered from the mains it is important to be aware that the chip will have lethal voltages on its pins and all appropriate safety guidelines **must** be adhered to. Early tests using an isolated variable transformer to provide an adjustable input voltage were unsuccessful but a mains transformer with tapped secondaries gave better results for test purposes. If the input mains filter is not fitted it is important to keep supply leads to the circuit as short as possible.

On the positive side the circuit does not employ large reservoir capacitors on the high voltage side so once the ReLED is disconnected from the mains supply any high voltages lurking around the circuit will be quickly discharged.

(030212-1)

Web Pointer
HV9901 datasheet from:
www.supertex.com/pdf/datasheets/HV9901.pdf

useful in some applications: The LED can be switched on and off by a logic signal applied to the ENI input (galvanically isolate this input logic signal via an optocoupler). The polarity of the ENI signal can also be inverted by changing the level on the POL input. The HV9901 also contains an auxiliary voltage regulator that can be used to power additional circuitry. Two resistors are used to program the auxiliary voltage in the range from 2 V to 5.5 V the maximum output current is only 1 mA but this is enough to power a couple of CMOS chips or a CMOS 555 timer or even a low power microcontroller so that many more applications can now be realised using flashing lights or timed light control etc. (**Figure 5**).

External circuits can also be powered from 9 V available from VDD, in this case the two resistors are not required and VCC is connected to VDD. The logic threshold levels of the ENI and POL inputs will also correspond to this supply voltage (**Figure 6**). The circuit flashes an LED (not shown) at approximately two-second intervals. The POL input is used to invert the sense of the timer output. In a similar manner a switch-on or switch-off delay can be simply implemented with some additional logic gates. Light level detector circuits or PIR movement detectors can also be powered from the HV9901.

Resistors connected to the H/D input of the HV9901 are used to program the relay pull-in and holding currents when the device is used to drive a relay coil but this feature can also be used to implement a simple dimmer when an LED is used in place of the relay (**Figure 7**).

The HV9901 can also be used as

OTL Headphone Amplifier with ECC82 (12AU7)

An 'iron-free' valve amplifier

Design by H.-J Friedli, PhD

A headphone amplifier with outstanding sound quality can be built using readily available modern components. Omitting the output transformer, avoiding overall negative feedback and using good coupling capacitors guarantees a highly linear frequency characteristic, while certain construction methods yield low channel crosstalk.

Measured values (with filter)

Supply voltage:	187 V
THD+N: (1 mW / 600 Ω)	2.3 % (right channel)
	1.86 % (left channel)
S/N: (1 mW / 600 Ω)	>93 dB
	>100 dBA
Filament supply ripple voltage:	30 mV$_{pp}$
Total power consumption:	17 W

Valve experts know that even power valves that can deliver several hundred milliampères of anode current can never drive a loudspeaker with an impedance of 8 Ω, since the internal resistance of a valve is several kiloohms. The two impedances are thus almost always matched using a transformer. In principle, there isn't any objection to using this form of impedance conversion, but every transformer tends to degrade the sound quality. Keeping this effect to a minimum requires very careful and complicated coil winding techniques, good-quality transformer iron and large core cross-sections.

However, if the load impedance is not just a few ohms but instead several hundred ohms, as is the case with many types of headphones, and if in addition the required power level is not overly high, an amplifier with no output transformer — sometimes referred to as an 'output transformerless' (OTL) amplifier — can be a feasible option. In this case, the load is driven directly by the valve.

The OTL amplifier described here is a cathode follower

The circuit

The circuit shown in **Figure 1** uses the readily available ECC82 double triode (equivalent to the North American 12AU7) to provide amplification. In Europe, 'special quality' (SQ) versions of this valve with better specifications and longer service life are also available under type numbers E802CC and E82CC, respectively.

A preamplifier stage is necessary to generate signal amplitudes sufficient to adequate drive a headphone. The triode section with base pins 1, 2 and 3 is used for this purpose. The input signal arrives at the circuit board via an external 50-kΩ logarithmic potentiometer (P1, not shown in the schematic) that serves as a volume control, and it is directly coupled to the preamplifier stage via C1. R1 provides the necessary negative grid bias. The gain is essentially determined by R8, while the maximum input voltage is determined by R2. R9 is dimensioned such that the quiescent anode current is situated in the most linear possible portion of the characteristic curve.

The inverted and amplified input signal on the anode is coupled to the grid of the second stage via C2. The cathode resistor of the second stage is split into two resistors (R5 and R6). The series resistance of R5 and R6 forms the load resistance, while the voltage division provided by the resistor pair allows the grid bias to be set to the proper level. The bias voltage is decoupled from the load and stabilised by R4 and C3 before being applied to the grid. The anode current flowing through the triode, which depends on the grid voltage and corresponding characteristic curve, generates a voltage across the combination of R5 and R6 that is exactly proportional to the current. This voltage is in turn fed to the headphone via coupling capacitor C4. R7 holds the output at ground potential for DC signals in order to avoid crackling noises when the headphone is plugged in.

design suitable for use with a single or dual headphone, with each headphone element having a rated impedance of at least 300 Ω.
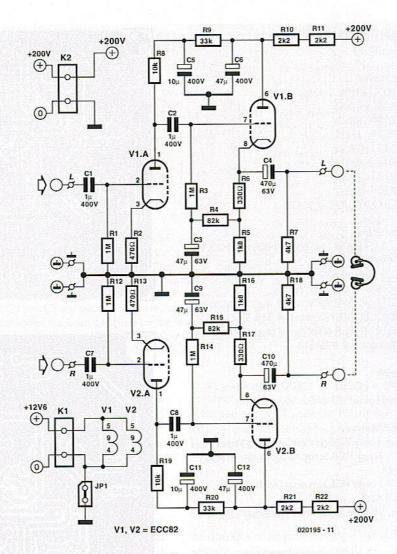
Figure 1. Schematic diagram of the amplifier using two ECC82 (12AU7) valves.
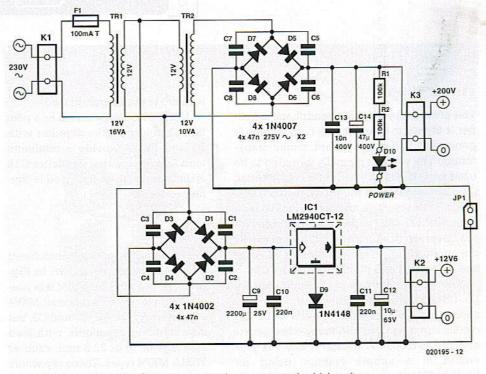
Figure 2. Two mains transformers are used to generate the high voltage.

COMPONENTS LIST
(Amplifier)

Resistors:
R1,R3,R12,R14 = 1MΩ
R2,R13 = 470Ω
R4,R15 = 82kΩ
R5,R16 = 1kΩ8
R6,R17 = 330Ω
R7,R18 = 4kΩ7
R8,R19 = 10kΩ
R9,R20 = 33kΩ
R10,R11,R21,R22 = 2kΩ2

Capacitors:
C1,C2,C7,C8 = 1µF 400V (MKP4 or MKS4, 250V)
C3,C9 = 47µF 63V radial
C4,C10 = 470µF 63V radial
C5,C11 = 10µF 400V radial, e.g., Panasonic ECA2GHG100n (Farnell # 219-9320)
C6,C12 = 47µF 400V radial (e.g., Conrad Electronics # 475858)

Valves:
V1,V2 = ECC82 or 12UA7, with Noval (9-way) socket (Chelmer Valve Corp.)
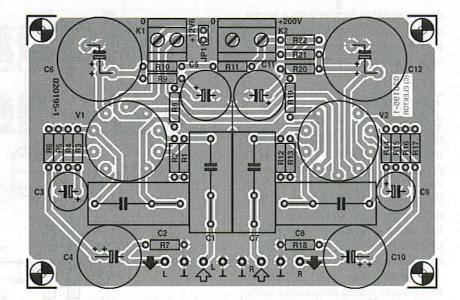
Miscellaneous:
JP1 = 2-way PCB pinheader with jumper
K1 = 2-way PCB terminal block, 5mm lead pitch
K2 = 2- way PCB terminal block, 7.5mm lead pitch
PCB, available from The PCBShop
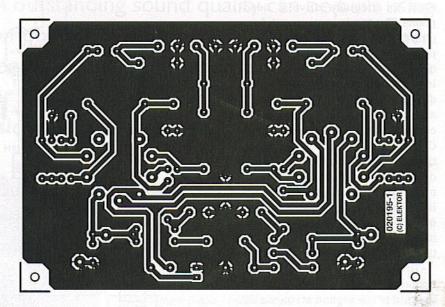
Figure 3. Layout of the amplifier printed circuit board.

Power supply

The power supply for the headphone amplifier is shown in **Figure 2**. The high voltage is generated using a standard mains transformer. The winding normally intended to be used as a secondary winding is connected to the 12-V terminals of the actual mains transformer. This results in an open-circuit voltage of around 200 VAC on the primary winding of the 'reversed' transformer, which serves as the anode supply transformer. This AC voltage is rectified and then smoothed by C14.

The DC filament voltage is rectified by D5–D8 and then smoothed by C15. The capacitors connected in parallel with the diodes suppress high-frequency noise generated by the diodes. A voltage of 12.6 V is generated in a simple manner using an LM2940CT12 (for low voltage drop) with a sil-icon diode in the ground lead.

LED D10 not only serves as a pilot light, but also works together with R1 and R2 to provide a minimum load and ensure that capacitor C14 is discharged, even if no load is connected to K3.

Layout

The layout of the printed circuit board for the amplifier, as shown in **Figure 3**, is designed such that it is possible to use not only 'normal' MKS4 capacitors for C1, C2, C7 and C8, but also coupling capacitors with lead spacings of 15 or 22.5 mm, such as WIMA MKP4 types. These capacitors have higher breakdown voltages and are physically larger, which makes them better for audio purposes.

For the large-volume electrolytic capacitors (C6 and C12), types with lead spacings of 5 or 7.6 mm can be used, or radial snap-in types with lead spacings of 10 mm. The latter type of capacitor has a larger diameter and thus absorbs less heat from the nearby valves. Low-inductance electrolytic capacitors designed for high-frequency switching applications should preferably be used, and in any case they must be specified for operation at 105 °C .
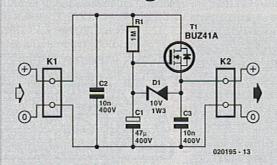
Power is supplied to the individual channels via the combination of R10 and R11 or R21 and R22, respectively. These resistors dissipate

around 0.18–0.25 W, depending on the supply voltage. Be sure to use resistors with adequate power ratings. There are resistors available that can dissipate 0.3–0.4 W with the same package size (such as 1/4-W metal film resistors), and the PR01 series from BC Components can even handle 1 W. In any case, it won't do any harm to fit these four resistors well clear of the circuit board in order to improve their cooling.

In the circuit board layout, attention has also been given to keeping the signal paths of the two stereo channels as widely separated as possible. The connections between the ground terminals of the four anode decoupling capacitors and the common ground point are routed separately for each channel. Incidentally, there is one wire bridge on the amplifier board (between C5/C11 and C1/C7).

The power supply circuit is housed on a second printed circuit board, to which the amplifier board can be attached in sandwich fashion. However, the amplifier is somewhat sensitive to the stray fields emanated by the transformers, whose magnitude depends on the type of transformer used. The 50-Hz components in the frequency spectrum (see measurement curves A and B) clearly indicate the presence of the two transformers, which were located at distance of 20 cm. Diodes D1–D4 are 'solid' 1N4002 types, but there is enough room for even more robust types. Capacitors C5–C8, which have a lead spacing of 15 mm, **must** be X2 types.

If you want to fully eliminate any ripple in the filament voltage, you can use a 15 V / 20 VA transformer for TR1. As this is a slightly larger type, it will not fit on the circuit board. Although the dissipation of IC1 will increase in this case, the specified heat sink is fully adequate. We also tried using a 15 V / 16 VA transformer, but it drew 23 VA from the mains (significantly overloaded). You are welcome to experiment with various transformers; a wide variety of results may be obtained, depending on the transformer type, open-circuit voltage, loaded voltage, core size, and material. The winding ratio is always determined by the design value of the open-circuit secondary

voltage. For a transformer with a nominal secondary voltage of 9 V, this can easily be 12 V.

To balance out the reactive power, an X1-type capacitor rated at around 150 nF / 250 V can be connected across the secondary winding of TR2. This will cause the anode voltage to actually increase slightly, but the mains power consumption and current will decrease by around 6–7 percent.

An advantage of using two trans-

formers is that the high voltage is isolated from the filament voltage. Nevertheless, the two ground potentials must be interconnected. This can be done on the amplifier board and/or on the power supply board (JP1).

Construction

Fitting the components to the circuit boards should not present any problems. All components are fitted on the 'normal' component side.

Anode voltage filter

The circuit forms a power RC filter that reduces the ripple component of an unstabilised supply voltage. Naturally, this results in a voltage drop of a few volts. Here a MOSFET suitable for use with high voltages (a BUZ41A, rated at 500 V / 4.5 A) is wired as a simple source follower. The gate is very slowly brought up to the desired voltage via the R1/C1 network. It takes four minutes (five RC time constants) for the output voltage to reach 99 percent of its nominal value. As the valves also take a while to warm up, this delay does not matter. The effect of using the filter can be clearly seen in Curve B.

The voltage drop across T1 is primarily determined by the gate–source cutoff voltage and is approximately 3.5–4 V. The gate is protected against excess voltages by Zener diode D1. C2 and C3 are necessary to eliminate the tendency of the circuit to oscillate. No circuit board layout has been designed for the filter circuit, but it can easily be built on a small piece of prototyping board. The filter dramatically reduces the amplitude of the ripple voltage.

020195 - 13

The voltage regulator requires a heat sink. Its cooling tab is connected to its middle lead, which is 0.6 V above ground potential in this circuit due to the diode.

As everybody knows, the electrolytic capacitors must be fitted with the correct polarity. However, it is also necessary to observe the proper polarity when fitting the four 1-µF capacitors. As the grid terminal is the most sensitive point in a valve circuit, it must be connected to the inner foil of the capacitor. The outer foil, which is sometimes marked by a stripe, then has a screening effect.

The Cinch sockets, potentiometer, phone socket and mains switch must be wired externally, which leaves considerable room for personal choice in selecting an enclosure and arranging the controls and connectors.

The circuit board layout (Figure 3) has been kept highly symmetric with

COMPONENTS LIST
(Power supply)

Resistors:
R1,R2 = 100kΩ

Capacitors:
C1-C4 = 47nF ceramic
C5-C8 = 47nF 275 VAC, Class X2, lead pitch 15mm
C9 = 2200µF 25V radial
C10,C11 = 220nF
C12 = 10µF 63V radial
C13 = 10nF 400V, lead pitch 7.5mm or 10mm
C14 = 47µF 400V radial (BC Components # 22215266109, Farnell # 322-7984)
(BC Components # 22215266479, Farnell # 322-8009)
Panasonic ECA2GHG470 (e.g., Farnell # 319-9356)

Semiconductors:
D1-D4 = 1N4002
D5-D8 = 1N4007
D9 = LED red, low current
IC1 = LM2940CT-12 with heatsink, Fischer type SK104 (50.8 mm)

Miscellaneous:
JP1 = 2-way PCB pinheader with jumper
K1,K3 = 2-way PCB terminal block, lead pitch 7.5mm
K2 = 2- way PCB terminal block, lead pitch 5mm
F1 = fuse, 100mAT (slow), with PCB mount holder
TR1 = mains transformer 12V / 16VA (ERA BV054-5383.0K (Conrad Electronics # 506575)
TR2 = mains transformer 12V /10VA (ERA BV048-5383.0H (Conrad Electronics # 506478)
PCB, available from The PCBShop

Figure 4. The power supply printed circuit board can be fitted to the amplifier board 'sandwich' fashion.
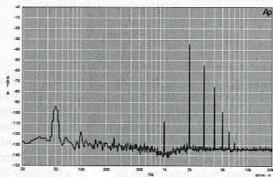
Curves and sound

Curve A shows the frequency spectrum of a 1-kHz signal (1 mW into 600 Ω). The distortion components (right channel) amount to 2.3 percent, but this is primarily due to the second harmonic. Besides this, an enormous effect can be seen from the ripple voltage of the unstabilised anode voltage supply. To remedy this, we developed an active filter (see box) that almost fully suppresses the 100-Hz component and its harmonics. The results obtained using this filter can be seen in Curve B. The third curve, C, shows the distortion as a function of output power. The distortion level increases quite linearly with the output power level. The amplifier 'runs out of room' at around 5 mW.
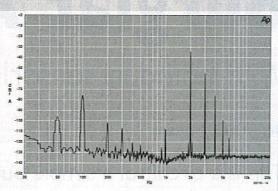
It's almost impossible to describe the performance of a piece of audio equipment using bare figures alone. The most noticeable aspect of the sound is dynamic range: what is supposed to be loud is loud, and what is supposed to be soft is soft. The sound is warm and spacious, and although it is perhaps slightly lacking in clarity of detailing at the upper edge of the frequency spectrum for high volume levels, this by no means reduces the enjoyment of opera voices. The sound is very pleasant and remains so during extended listening. Low tones do not present any problems, and it is certainly quite enjoyable to listen to music with strong bass components, such as rock, pop and jazz.
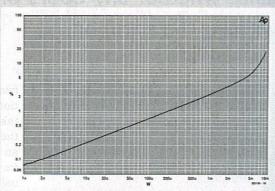
Measurement curve **A**. Frequency spectrum without a pre-filter for the anode voltage.

Measurement curve **B**. Using a filter provides a clear benefit, with significantly reduced 100-Hz components.
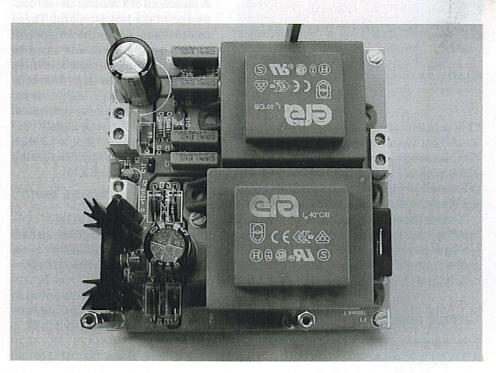
Measurement curve **C**. The distortion level increases linearly with output amplitude.

regard to its visual aspect, so there is no reason not to use an enclosure design featuring a visible circuit board with its valves and other components. If you would rather conceal the circuit board but still wish to have the valves visible, you should etch the circuit board using a mirror image of the layout. In this case, the tube sockets are fitted to the copper side of the board, with all other components being mounted in the usual manner so they face downward after the board is fitted in the enclosure. All polarisations remain the same.

All 230-V wiring must be made using wire with sufficiently thick insulation. It is essential to apply additional insulation to the solder points and fit an insulating sheet between the mounting panel and the undersides of the transformers. You must also provide for good ventilation. A double-pole on/off switch must be fitted in series with the 230-volt wiring. The transformers should be fitted in the enclosure as far away

as possible from the signal inputs. If the transformers are too close to the inputs, a typical 50-Hz hum will be

heard if the Cinch sockets are open and the volume control is turned up full.

(020195-1)

Burglar Alarm

With individual sensor signalling

Design by E. Martens

This is a circuit of a simple but effective burglar alarm, which shows the status of each sensor with a separate LED. This allows you to see at a glance whether any doors or windows aren't closed properly before switching the alarm on.

Main Specifications

– Maximum number of sensors that can be connected: 8
– Monitoring and signalling of each sensor for activation and cable continuity
– Tamper input
– Panic pushbutton
– Exit delay: 60 seconds
– Entry delay: 60 seconds
– Power supply: 230 V_{AC} or backup battery
– LEDs indicate:
   - alarm armed
   - alarm activated
   - tampering
   - backup battery active
– Outputs: 2 (12 V_{DC}, 500 mA)
– Alarm duration: 60 seconds

Please note: *Readers Circuits have not been tested or post-engineered by the Elektor Electronics design laboratory.*

This article describes a design of a burglar alarm that can monitor up to eight sensors. The status of each individual sensor is indicated with an LED. This LED shows whether the sensor has been activated and whether the wiring to the sensor is in order.

Obviously, this burglar alarm also has an input to 'arm' the alarm, a tamper input and a couple of outputs to control a siren and/or a strobe light. The alarm is also fitted with a so-called 'panic button'.

Circuit description

The burglar alarm is built around the AT89C51 microcontroller from Atmel. This microcontroller provides all the functionality of the burglar alarm. It also takes care of (software) filtering of the signals at the inputs. Only after an input has remained unchanged for 30 milliseconds, is this new signal level passed on for processing by the microcontroller program.

The schematic for the burglar alarm (**Figure 1**) is simplicity itself and only a small number of components are required.

Sensors

A maximum of 8 sensors can be connected to the burglar alarm. These can be found along the left side of **Figure 1**. These sensors need to have their contacts closed when in the inactive state (i.e. Normally Closed). In addition, each sensor needs to have its tamper connection wired as well. A power supply voltage of +12 V_{DC} is available for each sensor at the corresponding wiring terminals (K3 through K10).

Operation

The alarm is switched on by opening key switch S1, at which point the so-called 'exit-delay' begins. This time delay (60 seconds) allows you to leave the protected area without triggering the alarm. The alarm is deactivated when key switch S1 is closed.

If a sensor contact is opened when the alarm is armed and after the exit-delay has expired, the entry-delay (60 seconds) will begin. Under normal circumstances, the alarm will be deactivated with key switch S1 during the entry-delay. In the event of a burglary, the alarm will trigger after the entry-delay has expired. The entry-delay can only be interrupted by switching the alarm off with key switch S1.

The special 'panic button' S2, can be used for those situations — whatever the reason may be — that require the alarm signal to be activated. The alarm signal will be activated immediately, independent of the armed or disarmed status of the burglar alarm. The alarm will be silenced after 60 seconds or after pressing the panic button again.

Sabotage

The purpose of tamper input K11 is to detect tampering attempts when the alarm is armed. Possible scenarios are opening of the burglar alarm enclosure, the cutting of cables, etc. The tamper input needs to be normally closed (NC). A number of NC-contacts and wires can be connected in series (the cables to the alarm sensors, for example).

Signalling

Eight LEDs (D10 through D17) indicate the status of the corresponding
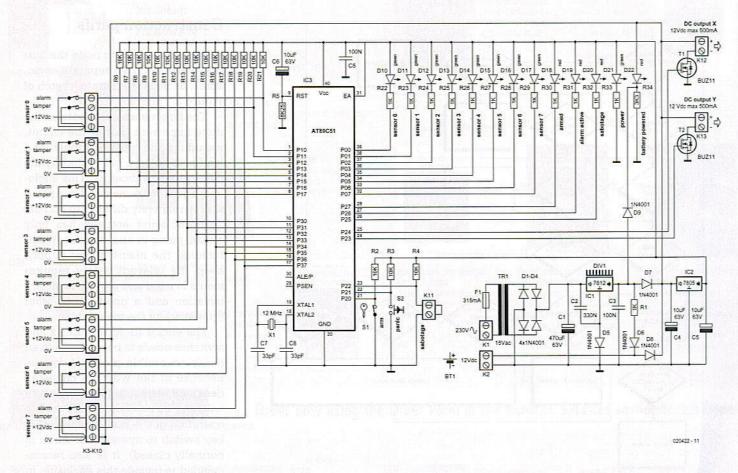
Figure 1. The alarm consists mainly of a microcontroller, a number of sensor inputs and a set of indicator LEDs.

sensors. When the alarm has been activated, the LED of the sensor that caused the alarm will light up, or flash in the event of a cable failure.

When the alarm is armed, the LED 'alarm armed' (D18) will flash during the exit-delay. After the exit-delay, the LED will light continuously. D18 turns off, of course, when the alarm is disarmed.

The LED 'alarm triggered' (D19) flashes during the entry-delay and will turn on continuously once an actual alarm has been generated. D19 turns off only when the alarm is switched off with key switch S1. When an alarm has taken place, it can be determined afterwards which sensor (or tamper input) caused the alarm to trigger.

The LED 'tamper' (D20) lights up when the tamper input (K11) is opened. This LED will also continue to be on until the alarm is switched off.

Finally, the LED 'battery operation' (D22) indicates that lead-acid battery BT1 has taken over the power supply for the burglar alarm.

Outputs

The burglar alarm is provided, from the viewpoint of reliability, with two separate outputs (K12 and K13). Both outputs are controlled by a BUZ11 (T1 and T2) and can switch up to 500 mA at 12 V. This is more than enough for all common signal sources such as strobe lights and sirens. If more power is required or a signal source with a different voltage needs to be controlled, then a 12-V relay can be connected directly to the alarm output and it in turn can then switch the signal source on and off.

Power supply

The circuit is provided with its own mains power supply. It follows the usual design of transformer, bridge rectifier (D1 through D4) and filter capacitor (C1) and generates an input voltage of about 18 V for voltage regulator IC1. With the addition of diode D5 in the ground connection, the output voltage if IC1 amounts to about 12.65 V. This volt-

age is subsequently reduced to about 12 V by diode D7. Voltage regulator IC2 in turn changes this 12 V into a stabilised 5 V power supply voltage.

In the event that the mains voltage at K1 disappears, the 12-V lead-acid battery connected to K2 will immediately take over the power supply for the circuit. The battery is continually being charged via resistor R1 and diode D6, when the mains voltage is present. D7 and D8 prevent the charging current from flowing in the wrong direction.

Software

The software that is required for the alarm is of a relatively simple design. The flow chart shown in **Figure 2** illustrates this. This really shows a kind of logical summary of all the things that have been described above.

After the reset-phase of the microcontroller, all the LEDs are switched on for a period of two seconds. This allows for a quick lamp test to check if all the LEDs are functional and are connected correctly.

In the source code for the software, the values for the various timers can easily be adjusted to suit your own requirements. It concerns the following timers:
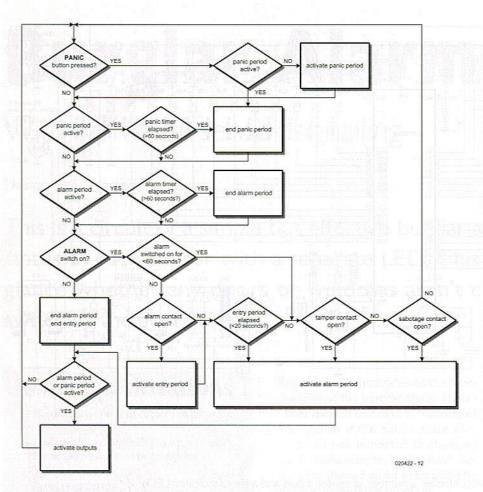
Figure 2. This flowchart makes it obvious how the software has been designed.

timer	variable	default (s)
panic timer	PANVAL	60
exit-delay timer	UITVAL	60
entry-delay timer	INLVAL	60
output X active	ALXVAL	60
output Y active	ALYVAL	60

Incidentally, the software for the burglar alarm (ref. no. **020422-11**) can be downloaded free of charge from the www.elektor-electronics.co.uk website.
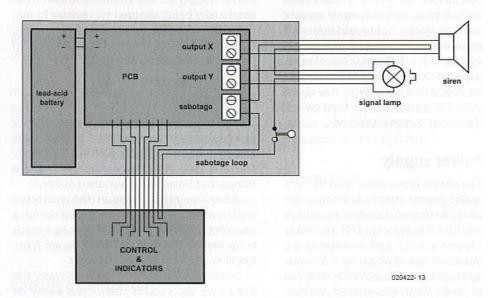
Figure 3. A practical implementation of the burglar alarm separates the control and indication from the other parts.

Construction perils

It is recommended to build the burglar alarm into two separate enclosures, as illustrated in the sketch of **Figure 3**.

The larger enclosure contains the more important part of the circuit, including the power supply and lead-acid battery, but excluding the controls and indicators. This enclosure needs to be mounted in a place that is relatively difficult to access. This enclosure actually has only cables going in and out of it. When building the mains power supply, keep the relevant safety requirements in mind and provide sufficient isolation and a good strain relief (grommet) for the mains cable.
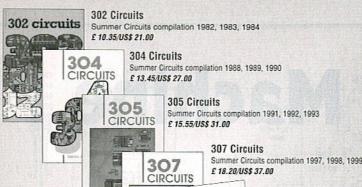
The enclosure for the LEDs and switches needs to be mounted in an easily accessible place, of course. Because of the way the circuit is designed, damaging this enclosure will have no influence on the correct operation of the burglar alarm (the key switch to operate the alarm is normally closed). It is also recommended to include this enclosure in the tamper circuit.

To prevent the burglar alarm from being easily circumvented without this being detected, it is necessary that the cables to the sensors are located in such a way that they are difficult to access. These cables can also be included in the tamper circuit.

A practical application of the tamper circuit is shown in **Figure 3**. A switch (normally closed) is also included in the tamper loop. This switch needs to open in the event that the enclosure is opened or vandalised.

If not all sensor inputs are being used, the alarm contact and tamper contact of each unused sensor needs to be shorted out.

(020422-1)

Relaxation Machine

A servo-powered pendulum

Design by B. Kainka

It is a generally known and accepted fact that servos used in radio-controlled models see very little or no use outside the model flying, racing or boating season. A pity, considering these devices can be used for many useful tasks…

For example, a servo that's not used anyway could be attached to a large pendulum of which the smooth and steady motion may help people relax and even fall asleep. For this (psychological) effect to be achieved the movement has to be sine-shaped like that of a real and very long pendulum.

The small circuit of the Relaxation Machine you find in **Figure 1** consists of two parts. A pulse generator based on a 555 supplies positive pulses with a length between 1 and 2 ms ('mark') and a pause of 20 ms ('space'), representing a typical servo control signal. In addition there's a sinewave generator designed to supply a very low frequency

of about 0.25 Hz which corresponds to one full period in four seconds. The sinewave generator employs a phase shifting network and supplies a sinewave with very low distortion. If you want to lengthen the period, simply increase the value of C1, C2 and C3 a little.

The generator drives the control input of timer component IC1 via an electrolytic capacitor. IC1, by the way, should be a 7555, 555C or another CMOS version of the 555. The generator drive scheme ensures that the timer 'mark' duration is con-

trolled, while the 'space' length is not affected.

A PCB was designed for the Relaxation machine (see **Figure 2**). Like all PCB designs that appear in this magazine the artwork files to enable you to make your own board may be found among this month's Free Downloads on the Publisher's website at www.elektor-electronics.co.uk.

With the board available, the circuit should be easy to build up. All you need to do is follow the parts list and the components mounting plan. There is one wire link on the board
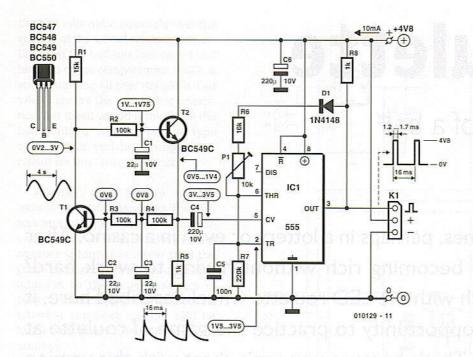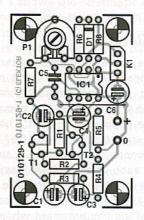
Figure 1. Circuit diagram of the Relaxation Machine.

Figure 2. PCB design.

Figure 3. Servo pinouts.

directions without hitting any of the stops. If the elongation (the distance the between a moving body and the point of origin) is too small or too large, you may need to experiment a little with the value of R1. If you make the resistors too small (<10 kΩ) then the oscillator will no longer oscillate. Capacitor C4, too, has an effect on the amplitude.

The current consumption of the circuit is of the order of 10 mA excluding the servo.

The 3-way pinheader in position K1 will allow most servos to be connected up easily. If you are using a 'less than standard' servo, then a small adapter may be required. The connections of a couple of well-known servos are shown in **Figure 3**.

Using our circuit, a correctly connected servo will turn slowly, describing a pure sinewave, its period being about equal to that of a pendulum with a length of four metres (!). Of course, you may also attach a smaller pendulum, a painted carton board or another ingenuous creation to the servo spindle, provided is not too large or heavy (because of the mechanical load on the servo).

The swinging pendulum has a relaxing effect, while the sound of the servo motor at such a low speed is not unlike snoring.

Warning

This circuit should not be used on (or by) persons with an epileptic or narcoleptic condition or subject to easy hypnosis.

(010129-1)

which should not be forgotten. The link is best made using thin isolated wire because it runs dangerously close to the pins of IC1.

Positions T1 and T2 can take almost any NPN transistors with a sufficiently high gain. In most cases,

this means that C suffix devices will work best, i.e., the h_{fe} should exceed about 300. Suggested types include the BC547C, BC548C, BC549C and BC550C.

Preset P1 is adjusted until the servo covers the full motion in both

COMPONENTS LIST

Resistors:
R1 = 15kΩ
R2,R3,R4 = 100kΩ
R5, R8 = 1kΩ
R6 = 10kΩ
R7 = 220 kΩ
P1 = 10kΩ preset

Capacitors:
C1,C2,C3 = 22µF 10V
C4, C6 = 220µF 10V
C5 = 100nF

Semiconductors:
D1 = 1N4148
T1, T2 = BC 549C
IC1 = 555C or 7555 (CMOS)

Miscellaneous:
K1 = 3-way pinheader
2 solder pins
PCB, available from **The PCBShop**
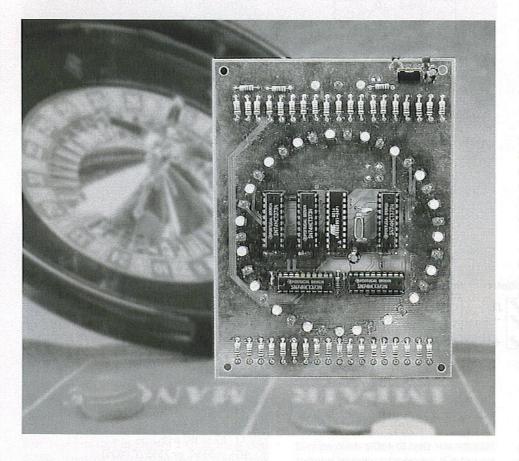
LED Roulette

using LEDs instead of a ball

Design by P. Goossens

Everybody gambles sometimes, perhaps in a lottery or even in a casino. After all, who doesn't dream of becoming rich without having to work hard? Although you can't win much with the LED roulette wheel described here, it does provide an excellent opportunity to practice the game of roulette at home in an honest manner. That's because you can't cheat with this version — the microcontroller that controls the LEDs doesn't take bribes!

The game of roulette has been known for centuries, and it is played all over the world. In order to make it easier to play this game at home, here we a present an electronic roulette game. This electronic version only replaces the turntable, which is the dished wheel used with a small ball to select a random number for each round of the game. You will have to make the playing field and the counters yourself.

Roulette

In the game of roulette, a random number is chosen for each round using a dished, spinning wheel within which a small ball circulates in the opposite direction. The ball ultimately lands in one of 37 compartments (numbered 1–36 and 0), with each compartment having a colour (black, red or green). The players can bet on the number, colour, etc, of the compartment where the ball ends up.

Roulette is not played very often at home, since it requires a proper roulette wheel. Any irregularity in the construction of the wheel will distort the probabilities and thus make the game unfair. A good roulette wheel is not cheap, and it also takes up a lot of space. An electronic version provides a solution to these problems: it doesn't cost a lot and it doesn't take up much space.

Implementation

In this circuit, the circulation of the ball is simulated by a number of LEDs arranged in a circle.

Our electronic wheel has more to offer than just a simulation of a circulating ball. As anyone who has ever visited a casino knows, at first

the ball rolls quite smoothly over the surface of the wheel when it is spun. But after the ball has lost speed and hits one of the compartment walls, it starts jumping all over the place. Our wheel shows the same characteristics, but if you would rather have the ball exhibit a 'wheel of fortune' type of behaviour, you can configure the circuit for this using a switch.

Another nice feature of our 'wheel' is that as soon as the ball has stopped, the circuit automatically indicates whether the present number is higher or lower than the previous number. This means that in addition to the usual manners of playing roulette, you can also bet on whether the next number will be higher or lower than the current number.

Schematic diagram

Figure 1 shows the schematic diagram of the roulette wheel. As is common nowadays with relatively complex digital circuits, it is based on a microcontroller.

In this case the microcontroller is an AT89C2051 (IC1), which requires only a small number of external components. C12 and R41 generate a reset signal when the supply voltage is switched on. X1, C1 and C2 ensure that the internal oscillator of IC1 generates a 12-MHz clock signal. The user controls are provided by a regular switch and a push-button switch (S2 and S1), each of which is directly connected to an I/O pin of the microcontroller.

The visual representation of the simulated ball is provided by 40 LEDs (D1–D40), with each LED having its own series resistor (R1–R40). The LEDs are driven by 8-bit latches (IC2–IC6).
LEDs D1–D37 are arranged in a circle, and they represent the various compartments of the wheel. LED D38 indicates that the value of the most recent spin is higher than that of the previous spin. By contrast, LED D40 indicates that the value of the most recent spin is lower than that of the previous spin. LED D39 lights up as soon as the 'ball' stops moving.
The circuit is powered by a 9-V
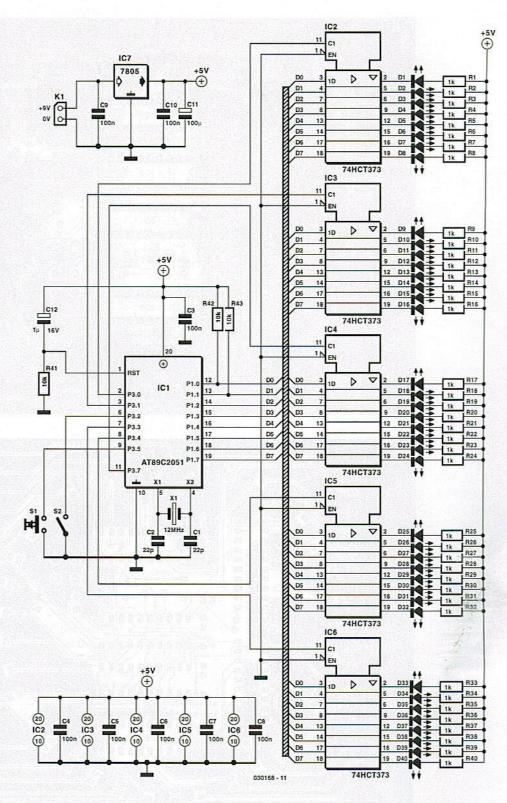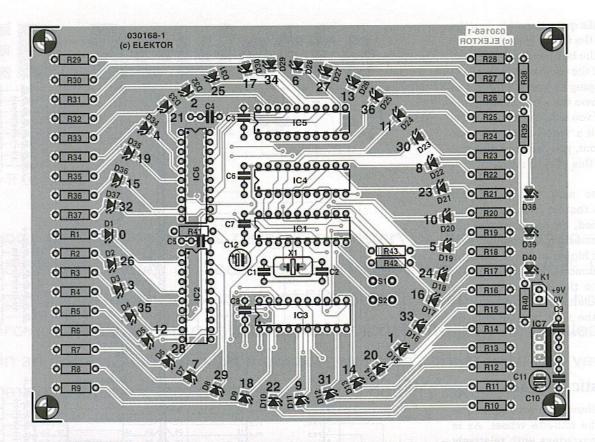
Figure 1. The schematic diagram of the roulette circuit: 40 LEDs controlled by a microcontroller.

battery, whose voltage is reduced to 5 V by IC7 to meet the demands of the digital components. Naturally, the necessary buffer capacitors and decoupling capacitors are also present in the circuit.

Resistors R42 and R43 are present because P1.0 and P1.1 are the only I/O pins of the AT89C2051 that do not have internal pull-up resistors. This allows these two ports to double as analogue inputs. However, in this circuit pull-up resistors are needed for all
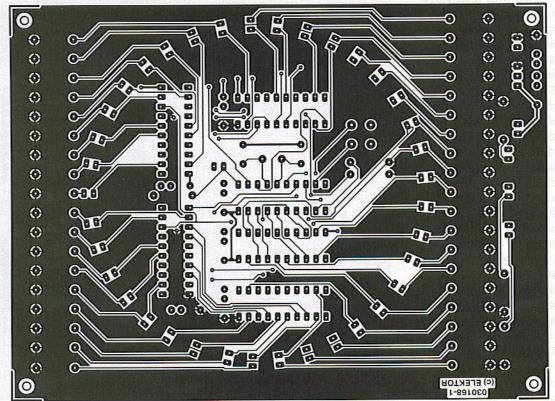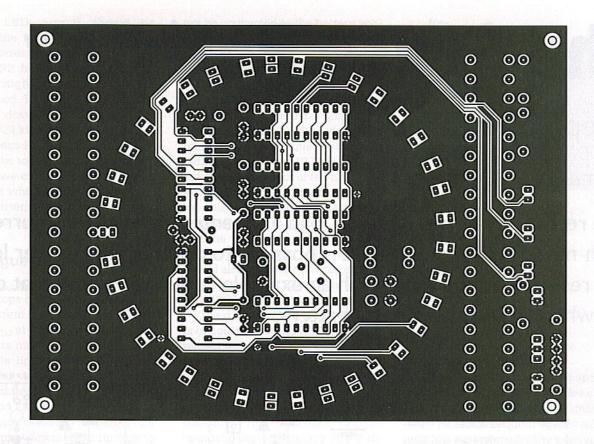
Figure 2. The double-sided printed circuit board holds the entire circuit except for the 9-V battery.

bits of port 1, so R42 and R43 have been added to ensure that a well-defined 'high' signal is also present on bits 0 and 1 when their outputs are not low.

Construction

Figure 2 shows the printed circuit board that has been designed for the

electronic roulette game. A double-sided printed circuit board is used here, because otherwise too many wire bridges would be needed to

COMPONENTS LIST

Resistors:
R1-R40 = 1kΩ
R41-R43 = 10kΩ

Capacitors:
C1,C2 = 22pF
C3-C10 = 100nF
C11 = 10µF 16V radial
C12 = 1µF 16V radial

Semiconductors:
D1,D38,D40 = LED, 3mm, green,
    low current
D2,D4,D6,D8,D10,D12,D14,D16,
    D18,D20,D22,D24,D26,D28,D30,
    D32,D34,D36,D39 = LED, 3mm,
    yellow, low current

D3,D5,D7,D9,D11,D13,D15,D17,
    D19,D21,D23,D25,D27,D29,D31,
    D33,D35,D37 = LED, 3mm, red,
    low current
IC1 = 89C2051-12PC, programmed,
    order code **030168-41**
IC2-IC6 = 74HCT373
IC7 = 7805CP (TO-220 case)

Miscellaneous:
K1 = 9V battery with clip and on/off
    switch (optional)
S1 = pushbutton with make contact
S2 = on/off switch
X1 = 12MHz quartz crystal
PCB, order code **030168-1**
Disk, contains source and hex code
    files, order code **030168-11** or Free
    Download

allow the LEDs to be arranged in a nice circle.

Little needs to be said about building the board. Just solder everything where it's supposed to be and you're all set. Of course, you must pay attention to the correct polarisation of the LEDs, ICs and electrolytic capacitors. Sockets can be used for the ICs, but they are not necessary if you have a certain amount experience with soldering.

If desired, all of the LEDs can be fitted on the solder side of the board, but that naturally depends on what sort of enclosure you plan to use.

The switches can also be connected to the board using lengths of wire, so they can be fitted at the side of the enclosure if so desired. You can also fit an on/off switch at the side of the enclosure and connect it in series with the battery connector (K1).

Conclusion

The software for the AT89C2051 was written in C and compiled using the Keil C51 compiler, for which (as you probably know) an evaluation version is available free of charge (http://www.keil.com/demo/eval/c51.htm). As the source and hex code are available from the *Elektor Electronics* website under number **030168-11** (and naturally on diskette as well), you can adapt the program to your own wishes if so desired. To do this, in addition to the compiler you will need to have a certain knowledge of the C programming language and a programmer for the AT89C2051.

If you have no desire to modify the program or do your own device programming, you can simply purchase a pre-programmed version from Readers Services (order number **030168-41**).

(030168-1)

Free Downloads

Microcontroller software.
    File number: 030168-11.zip
PCB layout in PDF format.
    File number: 030168-1.zip
www.elektor-electronics.co.uk/dl/dl.htm,
    select month of publication.

The Sense Resistor

in step-up converters

By K.-J. Thiesler

Sense resistors in series with the load are central to regulating current in switch-mode power supplies. It is possible to optimise the power loss in these resistors, as we show with an example converter circuit that drives eight white LEDs from a 4.8 V battery.

Switch-mode regulator ICs generally include a reference voltage generator and a differential amplifier. This combination is used to compare the voltage dropped across an external sense resistor with the reference and then suitably drive the output stage. The voltage drop across the resistor must be of the same order of magnitude as the reference, which in modern DC-DC converters is around 1.2 V. However, particularly when high currents are involved, this can mean an unreasonably large amount of power is wasted. With the following elegant circuit we can reduce the voltage drop across the sense resistor and hence reduce the power wastage.

Key points

Figure 1 shows a typical switching regulator configured to drive eight white LEDs from a 4.8 V battery supply. The switching regulator has to produce a voltage $U_{LED\ BIAS}$ across the LEDs of nominally $4 \_ 3.5\ V = 14\ V$. The voltage actually required in practice is not important here, since the LEDs are driven with a regulated current rather than at a regulated voltage. A DC current of nominally 40 mA should flow through each chain of LEDs.

Resistor R4 serves here as the sense resistor: the voltage U_A, which depends on the LED current, is brought to the feedback pin (pin 3) of the switching regulator IC as U_{FB}. The output is controlled so as to make the feedback voltage 1.233 V. In standard applications point A is connected directly to pin 3. Then $U_{FB} = U_A = R4 \cdot I_{LED}$, and the power dissipated in R4 can be calculated as follows: $P_{R4} = U_A \cdot I_{LED} = R4 \cdot I_{LED}^2$. With a feedback voltage of 1.233 V we require a sense resistor
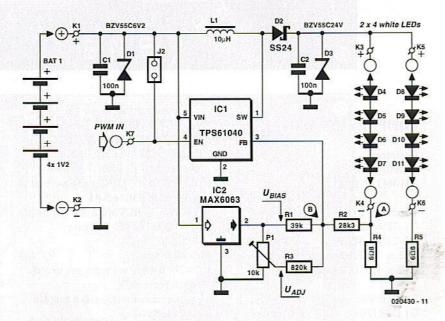
Figure 1. Modified step-up converter.

of around 30 Ω, and the power dissipated in it will be 50 mW.

The alternative circuit uses a resistor R2 in series with the feedback connection. A constant voltage source of $U_{BIAS} = 3.000\ V$ (generated by a MAX6063) is connected to point B via R1. Now, in order to generate a feedback voltage of 1.233 V, we require a much lower sense voltage at point A. Resistor R4 can be reduced significantly (to a theoretical value of 7 Ω), and the power dissipated in it is correspondingly reduced.

The circuit with the auxiliary voltage reference generator also gives

us a simple way to adjust the output current. To do this we also connect up a further voltage source U_{ADJ}, adjustable from 0 V to 3 V, via R3.

In order to calculate the resistor values, we start from the fact that a current of 45.3 µA will be flowing in R1 (39 kΩ). If U_{ADJ} is set at 1.233 V, then no current will flow in R3 and so this path will not have any effect on the circuit: all the current flowing in R1 will flow through R2. From the graph in **Figure 2** we can see that a voltage U_A of 144 mV corresponds to a voltage U_{ADJ} of 1.233 V, and so R2 should have a value of 24 kΩ.

The LED current should be adjustable from 0 mA to 50 mA. This corresponds to a voltage across R2 from 144 mV lower to 206 mV higher than the value just considered. To achieve the latter, R3 must draw a current of 206 mV/24 kΩ = 9.58 µA to ground. This means R3 should be 144 kΩ.

In order to calculate all the values exactly we can use Kirchhoff's current law, which states that the sum of the currents into a junction (here point B) is zero.

Analogue or PWM?

With U_{ADJ} at 3 V the switching converter stops operation and its quiescent current in this mode is 28 µA. With U_{ADJ} at 0 V the converter operates at its maximum frequency and the LEDs light at full brightness. Using this analogue control signal we can obtain adjustable brightness with good EMI emissions characteristics since there are no edges of a PWM control signal to get through to the LEDs. What may be a disadvantage is that the varying current through the LEDs results in a change in the emitted colour: the wavelength of the light emitted by an LED is dependent on the bias current. It is necessary to decide whether this shift in colour will be acceptable or not in each individual application. If analogue control of the output current is not desired, then connect U_{ADJ} directly to U_{BIAS} or simply omit the circuit involving R3 altogether.

Brightness control without affecting the resulting colour can be achieved using PWM. To this end the enable pin EN of the regulator should not be connected to the battery voltage: remove jumper J2 and instead drive EN from an external PWM signal via K7. This way it is possible not only to control the brightness from 0 % to 100 % in 'current mode', but also to exploit the brightness-enhancing effect of using double the nominal current pulsed at a frequency of 1 kHz with a duty cycle of 10 %. This gives the subjective effect of ten times the expected light intensity. In this case the values for R1, R2 and R4 need to be recalculated. At such a high current the voltage drop across a white LED can rise as high as 5 V, and this should also be taken into account. See also the article 'LED Arrays' in the April 2003 issue of *Elektor Electronics*.

The disadvantage of this method is of course that the LED current is pulsed and so the EMI characteristics are worsened. To mitigate this the LEDs should be mounted directly next to the regulator and the connections should be kept as short as possible. The datasheet recommends using a frequency of 100 Hz to 500 Hz at the enable input in PWM mode. In fact somewhat higher frequencies of 1.5 kHz to 2.5 kHz (but no higher) are more efficient. Below 100 Hz the pulses of light are visible to the eye. A PWM signal at a frequency of 1 kHz and an adjustable duty cycle in the range 0 % to 10 % is optimal both for the switching regulator and for the LEDs.

Components

Of course, the circuit as presented here is only a building block. Control circuitry, reverse polarity protection and overvoltage protection on the
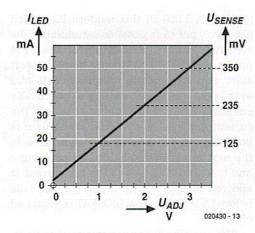
Figure 2. Effect of potentiometer voltage on LED current.

inputs all need to be added. Then the circuit has to be tested in practice. It's therefore worthwhile to take a brief look at the components used in the circuit.

The key component is the TPS61040 step-up converter, in an SMD package. The efficiency of this device when used as a current source is between 70 % and 85 %. The output voltage can go as high as 28 V, and so it is capable of driving up to six white LEDs. Internally the devices uses two-point regulation, and it can operate reliably with an output capacitor of only 100 nF. The peak current is regulated using pulse frequency modulation at a frequency of up to 1 MHz and the interval between pulses is guaranteed to be at least 400 ns. Stable operation with such a small output capacitor is only possible at such a high switching frequency. The voltage at the FB input is monitored using an internal comparator. The reference voltage U_{REF} is 1.233 V.

The internal power switch is turned off when the current through the coil exceeds 400 mA: this is the second point of regulation. The next pulse is started when the minimum interval between pulses of 400 ns has expired and the sense voltage U_{FB} has fallen below the sense voltage reference U_{FB}.

This regulation scheme runs in discontinuous mode, which means that as soon as the two criteria mentioned above are met the next cycle starts. The PFM switching frequency is therefore dependent on the input voltage, the output voltage, the inductance and the output current. The maximum pulse width is 6 µs. This way the device achieves its very high efficiency, without using external MOSFETs, over the entire range of load currents, and the tolerance of the coils and output capacitors is not critical to operation.

The switching current through the N-channel MOSFET is internally limited to a maxi-

		Standard	Modified
LED current	mA	40	
$U_{LED\ BIAS}$: 4 LEDs	V	14	
P_{LED}	mW	560	
U_{FB}	V	1.233	
U_A	V	1.233	0.387
R4 (E24 series)	Ω	30	10
P_R SENSE	mW	51	17
$P_{MAX6063}$	mW	0	0,5
P_{TOT}	mW	611	577.5
Efficiency	%	91.7	97.6

mum of 400 mA in this modern IC, which effectively prevents possible saturation of the coil by limiting the duration of the PFM pulses. Naturally the device features 'soft start' and can operate reliably at full load even with batteries that are practically exhausted. In the first group of pulses the current through the switching transistor is limited to one quarter of its maximum value; in the next group to one half of its maximum; and then after 512 pulses the full current is allowed to flow. If the input voltage falls below 1.5 V the internal MOSFET is switched off.

The effective series resistance of the output capacitor C2 has a significant effect on the efficiency and switching behaviour of this type of boost converter circuit. Normally a ceramic capacitor is required, but the TPS6104x can also manage with inexpensive tantalum capacitors. If a value greater than 100 nF is chosen — as would be required in applications where low output noise is important — the EMI emissions characteristics are made worse.

For the switching diode, a Schottky type with low leakage current is called for. The SS24 SMD diode in a type B package (DO-241 AA) from Fairchild is readily available and has a low forward voltage. Alternatively the 10BQ015 from International Rectifier (in the same package) can be used, or the more recent MBR0520LT1, a device with a low leakage current offered by ON Semiconductor in an SOD123 package.

The MAX6063 reference voltage generator, available in an SOT23 package, produces a precise output voltage of 3.000 V. The output noise is extremely low and no output capacitor is necessary. Its input voltage can be from 3.2 V to 12.6 V, and it has a negligible current consumption of 90 µA. If this boost converter circuit is used as part of a larger circuit, there will often be a reference voltage source already available which can of course be used instead of the MAX6063.

The inductor L1 is a tiny drum-core coil which can easily be made by hand. Be sure that the core material used is suitable for the switching frequency of the regulator. The DO1608C-103 by Coilcraft is ideal. In no circumstances should an ordinary suppressor choke be used.

Printed circuit board

When designing a printed circuit board it is essential to observe a 'switching supply' layout in order to keep the electromagnetic interference emissions as low as possible: SMD components, wide tracks kept as short as possible where high currents flow, and a ground plane on the underside of the board.

(020430-1)

Reference
The circuit is adapted from the article Extending Battery Life of a White Light LED Driver by Michael Day of Texas Instruments: the original is available on the Internet at www.chipcenter.com/analog/c071.htm.
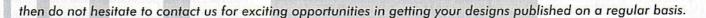
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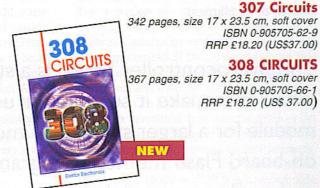
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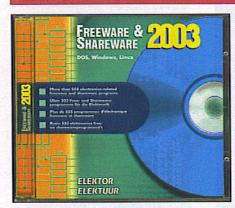
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Just like previous editions, the crop of 2003 supplies all ingredients to allow the modern electronics kitchen to cook and serve a wide range of recipes ranging from appetizers and cocktail snacks right up to the main dish, not forgetting salads and desserts, of course. The ingredients are hundreds of programs that can be run on various operating systems, linked directly or indirectly to electronics in general, programming, microcontrollers for sure, but also to many allied areas.

Besides the usual sections (CAD, Audio, Calculation Tools, Programming, Simulation, etc.) the 2003 edition of the Freeware & Shareware CD-ROM contains a collection of 'must-haves' which are not specifically linked to electronics, but valuable when it comes to writing or manipulating programs and files (assembly code, C, Delphi and others). This collection comprises utilities like xnView (for graphics file visualisation), dirprint (file, directory and subdirectory listing), Total Commander (previously known as Windows Commander) and other ingenious tidbits covering functions like file renaming.
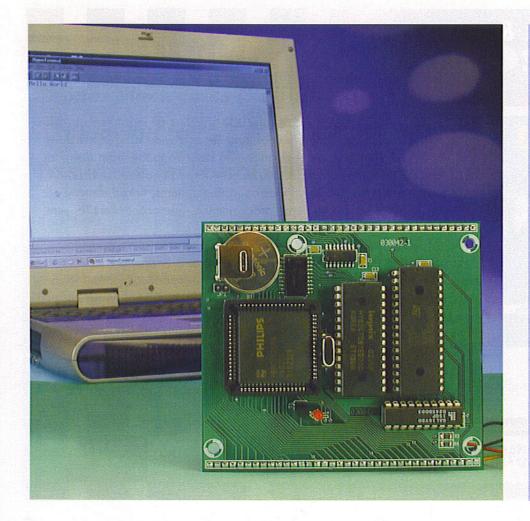
64-K 80C552
Flash Board

Inexpensive, multifunctional and in-circuit programmable

Design by L. Hamers

This microcontroller board is a standard 8051-based system, with a few extras that make it suitable for use as a development system or control module for a larger system. Its most important features in this regard are on-board Flash memory programming via the serial RS232 port, direct on-board program debugging and low cost.

Features

– 80C552 microcontroller clocked at 11.0592 MHz

– 64 KB Flash ROM, 32 KB RAM

– in-circuit programmable (max 64 KB)

– compatible with the MSC1210 source code debugger for in-circuit debugging

– address logic fully implemented in GAL

– nine chip-select signals for external devices connected to the data bus

– eight 10-bit A/D inputs or eight digital inputs

– eleven free I/O pins

– I²C bus

– watchdog timer, battery voltage monitor, RAM backup battery

– true RS232 interface (MAX232)

– two 36-way pin headers (2.54 mm) for all connections
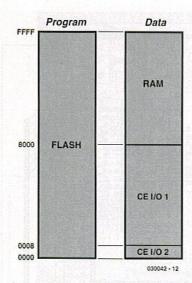
Figure 1. Flash ROM configuration in normal mode.
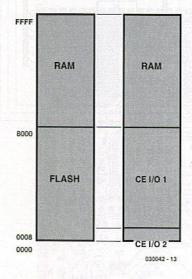
Figure 2. Flash ROM configuration in debugging mode.
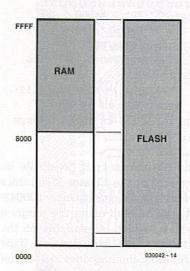
Figure 3. The third mode is used to program the Flash ROM.

A variety of microcontroller boards based on 8051 successors have already been published in *Elektor Electronics*, but this one has several features that clearly distinguish it from the rest. Read on to learn the details!

Operating principle

Normally speaking, with a microcontroller the program is read from the ROM, while the RAM is used to store variables and data. However, during software development it is handy to also have the program in RAM, since this allows it to be easily and quickly modified. For programming the Flash memory, it is also necessary to have the program in RAM, since is it not possible to program a Flash ROM and execute a program from it at the same time. It is thus necessary to have a mechanism for switching back and forth among various operating modes. The following modes are possible:
– debugging
– Flash programming
– normal

The 80C552 microcontroller can only address 64 KB of the Flash memory, since it has only 16 address lines. In debugging mode, part of the Flash memory must be used for the monitor program, which reduces the amount of memory available for the application program in normal mode. As the 29F010 Flash ROM has a capacity of 128 KB, half of it is not being used. However, with a bit of clever circuit design we can use the A16 address pin to switch between the two halves of the Flash ROM under control of a port line, which we call Debug/Run (or D/R for short).

Normal mode (Figure 1)
This mode is used after program development has been completed and the board is built into a stand-alone system. In normal mode, the Flash ROM is used as program memory over the entire memory address range of 0000 to FFFF (64 KB). The D/R (Debug/Run) line is set to '0' in this mode, which means that A16 of the Flash ROM is also set to '0'.

The program for the normal mode is located in the lower half of the Flash ROM in the address range

between 00000 and 0FFFF (here an extra digit is used compared with normal addresses because the ROM is twice as big as the normal 64-K address region).

For data memory, there are 32 KB of SRAM in the address range from 8000 to FFFF. Memory-mapped I/O devices can be connected in the lower, unused portion of the data memory address range (0000 to 7FFF). A total of nine chip-select signals are available for this purpose: $\overline{CE0}$ through $\overline{CE7}$ for addresses 0000 through 00070, and $\overline{CE\ IO1}$ for the remainder of the region (0008 through 7FFF).

Debugging mode (Figure 1)
The software provided with the MSC1210 development platform recently described in *Elektor Electronics* includes a source-level debugger called SLD51. This debugger lets you to copy a program to the board via the serial port and then the run the program, stop it, allow it to run one step at a time, and examine variables. It is also possible to set breakpoints, which cause the program to stop at certain points so you can look for problems.

In debugging mode, the Flash address range from 10000 to 17FFF is mapped onto the range 0000 through 7FFF for the microcontroller. This part of the Flash memory contains a combined operating system and monitor program called OS552. As the port lines of the microcontroller are set to '1' following a reset, the monitor program is started at Flash address 10000 after a reset. The upper 32 KB of the Flash memory cannot be used, since the RAM is addressed as both program and data memory in this range.

This is necessary for two reasons. First, it allows a given program to be tested in memory (RAM) using the monitor program, and second, it makes it possible to run this program. Memory-mapped I/O is located in the same region as in normal mode, so it can also be tested during debugging.

Programming mode (Figure 3)
The third mode is used to program the Flash ROM. As it is not possible to erase and reprogram the Flash ROM while the program intended to control this process is being executed from the Flash memory, it is necessary to make certain changes to the memory organisation. Here the RAM is used as program memory, and the Flash memory is used as data memory (which means it can be written). The chip-select signals for memory-mapped I/O are disabled in order to avoid undesirable effects on external circuits.

The firmware for programming the Flash memory must be written to RAM in advance. The PC program FlashMon does this automatically.
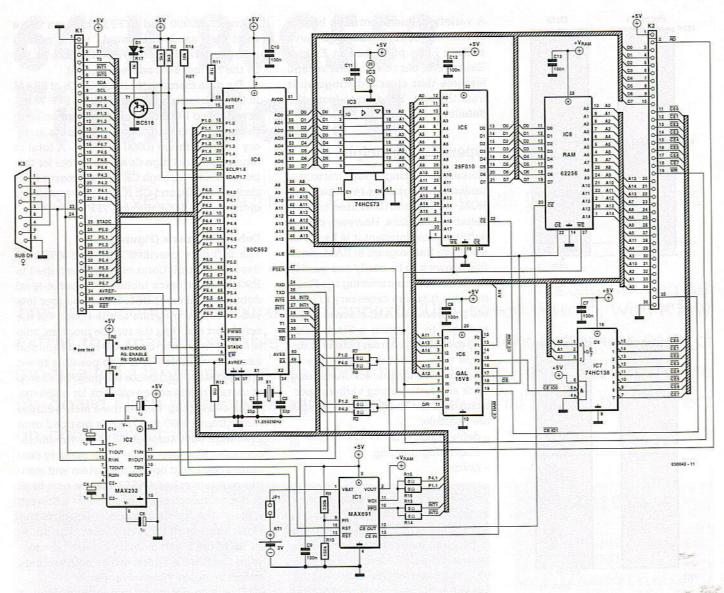
Figure 4. The full schematic diagram of the microcontroller board.

The circuit

Processor and memory

Figure 4 shows the complete schematic diagram of the microcontroller board. The various elements that make up the circuit can be quite easily recognised.

The microcontroller is a Philips 80C552 (IC4). Its most important added features compared with a standard 8051 microcontroller an I²C interface, an 8-channel 10-bit A/D converter, and an extra I/O port. As usual, the lower eight bits of the address bus are multiplexed, and they are separated from the AD signals by IC3.

A 32-KB RAM (IC8) and a 128-KB Flash ROM (IC5) are connected to the address bus. Only 96 KB of the Flash ROM is actually used. The central address decoder is a 16V8 GAL (IC6), which generates the control signals for both memory ICs and the memory-mapped

I/O. The $\overline{PSEN}$ and $\overline{RD}$ lines are used to generate output-enable signals in the address regions where these signals are necessary.
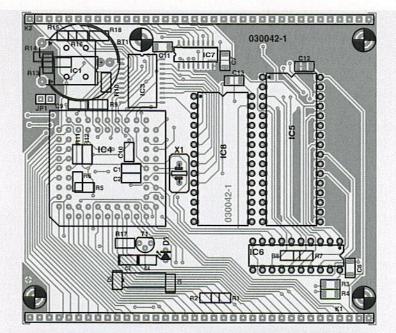
GAL
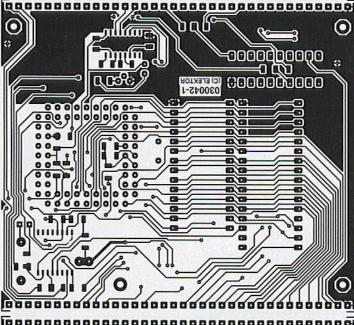
The GAL is the central element for switching between the various operating modes of the system. Several processor signals are applied to its inputs, including PGM (which causes the GAL to switch to the programming mode when it is '0') and D/R ('0': normal run mode; '1': debugging mode). The GAL outputs control the memory ICs and the chip-enable signals for memory-mapped I/O. The GAL programming description is as follows:
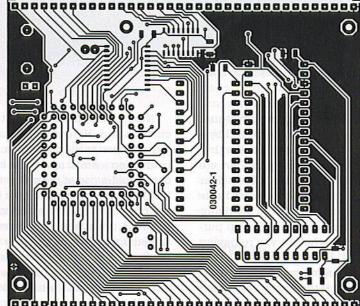
```
/OE = /PSEN*/RD
```

```
/CE_RAM = /A15+/PRG*/PSEN
   +/WR*/RD*/D_R*PRG
   +D_R*/RD*/WR*/PSEN
/CE_ROM = PRG*/PSEN
   +/WR*/RD*/PRG+D_R*A15*PRG
/CE_IO0 =
   /(/A11*/A12*/A13*/A14*/A15*
   PRG*/PSEN)
/CE_IO1 = A15+CE_IO0+/PRG+PSEN
A16 = D_R
```

The file upboard.pds (available on diskette or the Elektor Electronics website under order number **030042-11**) can be read using the program Palasm, which is available on the Internet as freeware. However, if the GAL programming does not require any modifications, it can be programmed directly using the JEDEC file upboard.jed.

I/O

All signals necessary for connecting external hardware are fed out via headers K1 and K2. Besides the full data and address buses, they include several chip-select signals that can be used to directly drive external memory-mapped I/O devices. Signals $\overline{CE0}$ through $\overline{CE7}$, which correspond to addresses 0000 through 0007, are output via address decoder IC7.

If even more control signals are needed, the $\overline{CE\ IO1}$ signal can be used to handle the remainder of the I/O range (from 0008 to 7FFF). If a MOVX command is executed in this region, the $\overline{CE\ IO1}$ signal goes to '0'.

The 5-V signals from the serial port of the microcontroller are converted to genuine RS232 levels by the MAX232 (IC2), in order to allow the circuit to be connected directly to a PC. If RXD and TXD are connected as shown in the schematic diagram, it is not necessary to use a null modem cable; a regular 1:1 serial cable can be used instead.

The 80C552 has a full I^{2}C interface that supports the complete standard in both single-master and multi-master modes. Activity on the clock line of the bus is indicated by LED D1. This line is also used by the monitor program to display system status during start-up by means of blink codes.

The A/D inputs (P5.0–P5.7) are connected directly to K1. The supply voltage for the microcontroller serves as the reference voltage. If this is not sufficiently accurate, resistors R11 and R12 can be removed and an external 5-V reference voltage can be connected to K1.34 and K1.35.

Power supply and protection

A small (70 mA minimum), stabilised 5-VDC supply can be used to power the microcontroller board. The circuit is protected against an insufficient supply voltage by IC1. This IC (a MAX691) has been specially developed for such tasks, and it generates a reset pulse immediately after power is applied.

If the voltage on the microcontroller drops below 4.5 V, it is placed in the Reset state, the RAM is powered from the backup battery (if JP1 is fitted) and the RAM is put into standby mode. If the voltage drops below 4.6 V, PF0 is set to '0' (the voltage level can be adjusted using R9 and R10; the threshold voltage of the PF1 input is 1.3 V). If R13 and R14 are fitted, this can be used as an early indication that the supply voltage is collapsing.

Figure 5. SMD components are used to keep the printed circuit board nicely compact.

IC1 also includes a watchdog timer, just in case the watchdog timer in the 80C552 is not sufficiently safe. The watchdog is enabled or disabled by soldering R15 or R16 in place. If you would like to know more about the MAX691, you will find its data sheet at www.maxim-ic.com.

Circuit board assembly

The circuit board layout designed for this circuit is shown in **Figure 5**. SMD components have been used to keep the circuit board very compact. This makes assembling the circuit board somewhat more difficult, but with a fine soldering tip and a steady hand, you should be able to manage it without too many difficulties. Incidentally, a bit of desoldering braid works wonders if things occasionally go wrong.

First fit all of the resistors to the board. The values of SMD resistors are printed on them using three or four digits. The final digit always indicates how many zeros have to be placed after the value. For instance, '333' means '33' followed by three zeros, which amounts to a resistance of 33 kΩ. However, a marking of '3302' ('330' and two zeros) also indicates a value of 33 kΩ.

A variety of options can be selected by fitting 0-Ω resistors, which are used as jumpers. (If you find it difficult to obtain such resistors, you can also use 1-Ω resistors or wire bridges instead.) The following settings are the standard values, for which the software is configured:

Function	Fitted	Open
Debug/Run mode	R1	R2
Disable watchdog	R6	R5
Programming mode	R7	R8
Reference potential +	R11	–
Reference potential –	R12	–
'Low voltage' interrupt	–	R13/R14
External watchdog	–	R15/R16

When software is being developed, it is a nuisance to have to repeatedly reset the watchdog timer (internal or external), and this often leads to problems. Besides this, neither of the watchdogs is serviced by OS552. This means that it is better to not use the watchdog until the major portion of the software is finished. Resistors R15 and R16 are thus not fitted initially.

Once you have soldered all the resistors, you can fit the ceramic capacitors. Be careful not to mix up the 33-pF and 100-nF types. These SMD capacitors all look the same, since no value is printed on them.

After this, fit the electrolytic capacitors in the vicinity of IC2. It hardly needs saying that it's vitally important to observe the correct
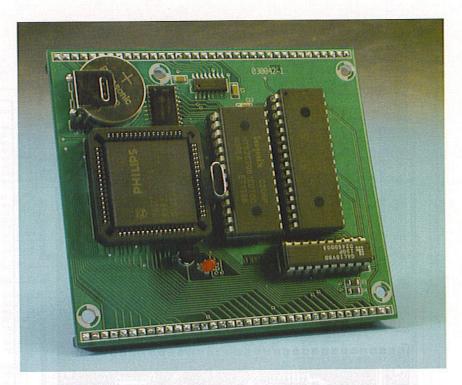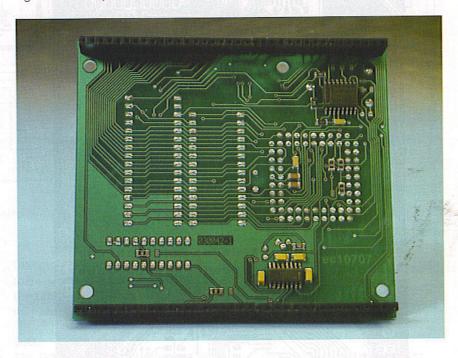
Figure 6. The fully assembled circuit board.

polarity. For rectangular electrolytics, the positive terminal is marked by a small + sign or a thick stripe, but electrolytics in round packages are just the opposite; they have their negative terminal on the side marked with black paint. No doubt the manufacturers did this on purpose to see whether you're paying attention! In any case, it keeps things interesting, because electrolytics fitted the wrong way round occasionally tend to explode.

Next, solder the SMD ICs to the circuit board. Here you also have to pay attention to the orientation. Start by melting a small amount of solder onto a solder pad at the corner of the IC. Using tweezers, place the IC on the board and use the soldering tip to press down the pin above the tinned solder pad. Once the IC is firmly attached, solder the pin at the opposite corner. Now check the positioning of the IC, which can be altered if necessary by warming the

soldered pin and shifting the IC. Once the IC is properly positioned, you can solder the remaining pins. Allow the IC to cool down after soldering each pair of pins, so it does not become overheated.

After all of the SMD components are in place, you can fit the IC sockets and connectors to the board. Make sure that the sockets are correctly oriented, particularly the PLCC

socket. There is usually a 'flat' on one of the corners. Finish the soldering work by fitting the transistor, the LED, the battery and the crystal. Finally, press the four ICs into their sockets. Note that before being fitted, the GAL (IC6) must be programmed using the file upboard.jed and the Flash ROM (IC5) must be programmed using the file upboard.hex. If you cannot do this yourself, you can order pre-programmed versions from Readers Services (order numbers **030042-21** and **030042-31**).

A fully assembled version of the circuit board is shown in **Figure 6**.

Testing the assembled circuit

For testing the circuit board, you can stick a few loose pins into connector K1 for the connections or use a piece of perforated prototyping board. Mount two pin headers on the prototyping board, each with 36 contacts. Connect pins 23 and 24 of K1 to pins 3 and 2 of a female sub-D connector, and connect ground (pin 1 of K1) to pin 5, pin 1 to pins 4 and 6, and pin 7 to pin 8.

Next, connect the board to a PC using a 1:1 serial cable and start a terminal emulator program (such as HyperTerminal). Configure the serial link for 57.6 kbit/s, 8N1, no handshake. If you now connect a power source to the board (5 V at 70 mA minimum), the message 'Hello World' will appear on the screen. This will be repeated if you press a key. The file *upboard.hex* programmed into the Flash ROM contains a small application program in addition to the monitor. The only thing this program does is write 'Hello World' to the outside world. Congratulations – you now know that your system is alive!

If the Flash ROM has not been programmed, nothing will happen. You can't program the monitor into the Flash ROM yourself, because the board needs the monitor for programming (what a pity!).

Software

The combined monitor and operating system program for the board is called OS552. It is a slightly modified

version of OS535, which is used with the MSC1210 development platform. This forms part of a complete development system including a C compiler, a project manager with 'make' files and a debugger. As OS535 was developed for a different board with an 80C535 microcontroller, several small modifications are necessary, among other things with regard to driving the GAL.

You can use the board in three different manners, assuming you have fitted a Flash ROM containing the monitor program:
1) To program the board, run the program FlashMon on your PC. This allows you to program up to 64 KB of the Flash memory.
2) To debug a program you have written yourself, run the program SLD51 on your PC. The maximum available memory is 32 KB.
3) To run a program you have written yourself (maximum size 64 KB), first program it into the Flash memory and then reset the board. You can also run a terminal emulator program on the PC, but not FlashMon or SLD51. The board will now run your program. The monitor program is located above the 64-KB boundary in this mode and does not affect the operation of the board.

These operating modes are described in more detail below.

Simulator

Software can be developed and debugged using the program SLD51. To use the board in this mode, select the proper COM port under Options/Com Settings and set the bit rate to 57,600. After the board has been switched on, it will remain in debug mode. You can use File/Open and File/Download to load a program into the RAM, where it can subsequently be run. The program located in directory \src\hello_debug can be used as an example for this purpose.

FlashMon

The program FlashMon from the µC51 development environment can be used to erase the Flash ROM on the board and reprogram it. To do this, first copy the file flashmon.bix into the bin directory of the development environment. Then start the FlashMon program. Under Options/Com Settings, set the bit rate to 57,600 and select the proper COM port. To prevent the program in the ROM from starting, enabled 'Disable Flash Autostart' in the Toolbox menu.

When the board is switched on, the start-up of the regular program will be intercepted and the internal monitor program will be started instead. Now you can use Toolbox/Clear Flash All to erase the program in the Flash ROM (the monitor program will

Summary of 8051 microcontroller boards

Unlike one competitor who appears to be stuck with PICs, *Elektor Electronics* has already published quite a few development board designs for microcontrollers in the 8051 family. Here we briefly describe the most important ones:

89S8252 Flash Micro Board:
a simple system for programs up to 8 KB, targeted at both experienced and novice users. Also provides the basis for a programming course that explains the basics of microcontroller technology and examines several programming languages (assembler, BASIC-52 and the Reads11 C compiler). Published in the December 2001 through June 2002 issues, with an I/O extension in January 2003.

High-speed Controller Board:
the DS89C420 is a super-fast 80541 derivative that can be used for processing rates up to 33 MIPS. An ideal development system, with 16 KV of Flash program memory and in-circuit programming capability. Described in the June and September 2002 issues.

XA Development Board:
with a PC/104 interface for 16-bit microcontrollers, 64 KB of program memory and 64 KB of RAM. The XA family was presented as a 16-bit successor to the 80C32, but it essentially goes much further. The XA core is considerably faster than its 8-bit predecessor. Described in the May and June 2003 issues.

MSC1210 Development Platform:
a small but powerful board built using SMD technology, which unlike the other boards described here is supplied ready-made (no soldering required!). Can handle programs up to 8 KB (8 KB development, 16 KB max in Flash), but has additional I/O and 24-bit A/D inputs. Includes a free Basic and C development environment. A digital measuring instrument using this board has already been described as an application. Published in the July/August through November 2003 issues ('Precision Measurement Central' series).

64-K 80C552 Flash Board:
a classic design for programs up to 32 KB (32 KB development, maximum 64 KB in Flash), with in-circuit-programmable Flash memory and 32 KB of RAM. Has eight 10-bit analogue inputs and three sets of 8 free I/O lines. Uses the same development environment software as the MSC1210 development platform (with minor modifications).

---

not be erased) and Toolbox/Download to Flash to write the new program to the Flash ROM. Note that this program must contain the instruction LJMP (0x02) at address 0000, since otherwise it cannot be started by the monitor program. The program located in .\src\hello_run, which is already included in the standard firmware, can be used as an example.

Monitor operation
Immediately after starting up, the board enters the debugging mode and the OS552 monitor program sends a command to the PC. If a program such as FlashMon is running in the PC, the PC sends back a command to the board to cause it to remain in the debugging mode.

Once this has happened, the monitor waits for commands from the PC, and the LED on the board flashes regularly. If no command is sent to the board after it is switched on, the monitor checks whether a LJMP command (with destination 0x02) is present at address 0000 of the Flash ROM. This is how the monitor recognises whether a valid program is present in the Flash Memory. The board then switches to the run mode and starts program execution at address 0000 in the Flash memory.

(030042-1)

BiM2 High-Speed Radio Transceiver

Using surface Acoustic Wave (SAW) technology, the BiM2 is an enhancement to Radiometrix's renowned BiM module, and it offers all the advantages of the latter but with greatly improved receiver interference rejection together with higher data rates and greater transmit power. More-over, with its low profile of 4 mm and small footprint (23 x 33 mm), together with the low power requirement, the BiM2 is ideal for PCB installation.

A major feature of the BiM2 module is the SAW-controlled 10mW FM transmitter plus front end SAW filter and full screening for EMC. The BiM2's transmit section comprises a SAW stabilised and FM modu-lated 433.92 MHz (European licence-exempt frequency) oscillator feeding a 10 mW power amplifier stage. Many radio transceiver modules on the market use crystal tech-nology but SAW provides a number of significant advan-tages, including lower cost, better data rate, low power consumption and faster power-up time. The SAW con-trolled BiM2 is the perfect choice for a wide range of bi-directional wireless connectiv-ity applications in battery-powered and hand-held equip-ment at ranges up to 200 m. The BiM2 provides data rates up to 160 kbps, features a dou-ble conversion FM superhet receiver and operates from a 3 V or 5 V supply at <20 mA. The module is verified to com-ply with both Radio standard ETSI EN 300 220-3 and EMC standard ETSI EN 301 489-3 by UKAS accredited Test Labora-tory. BiM2 is certified by an independent Notified Body.

**Radiometrix Ltd.,
Hartcran House,
Gibbs Couch, Watford
WD19 5EZ.
Tel. (+44) (0)20 8428 1220,
fax (+44) (0)20 8428 1221.
Internet:**
www.radiometrix.com
Email:
info@radiometrix.com

(037164-1)

Catch all your Data in the Web

A data logger which automati-cally uploads its measure-ments to an Internet database. The data can then be accessed and analysed with a standard web browser. Alarm condi-tions can trigger an SMS text message or an e-mail. All you need is mains or battery power and access to a tele-phone line.

Getting started with the SWI 300 couldn't be easier. Simply connect the unit to a tele-phone socket, plug in the power supply and switch the unit on. Once installed the unit can be controlled entirely through your Internet browser. Simply logon to where you can set the parameters that the logger will measure, the fre-quency of the sample and the intervals between upload. The website allows a user to set alarm levels and have an auto-mated e-mail or SMS message to alert you if these levels are exceeded and you can even operate remote devices through the unit's control relay

output. Each time the unit connects to the Internet it checks for new configuration settings and updates itself accordingly.
With an appropriate sensor the unit can be set to measure a whole range of parameters, from temperature to humidity, voltage and current. The data is accessed securely through and can either be viewed online in graph form or exported to most popular spreadsheet programs for fur-ther analysis.

The SWI 300 is available now for £349.95, which includes the first year's hosting for free.

Visit or for more information.

**Lascar Electronics Limited,
Module Hose, Whiteparish,
Salisbury, Wiltshire SP5 2SJ.
Tel. (+44) (0)1794 884567,
Fax (+44) (0)1794 884616.
Internet:**
www.lascarelectronics.com

(037164-2)

Miniature Web Server

Compulogic have announced the release of a new miniature web server product aimed at 'web enabling' existing or new systems and equipment.
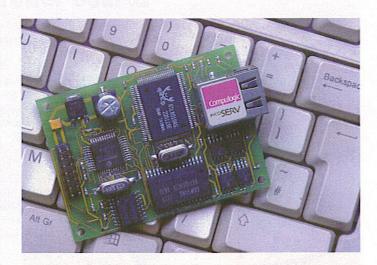
The PicoServ miniature web server module is an 'Internet engine' designed to provide a browser based interface over the Internet or a LAN in a small space, at low power, at low cost and with little or no design effort.

The PicoServ module takes care of all network interfacing and communications protocols, web page and file storage and provides a variety of simple interfaces to the host system or equipment. Dynamic web pages are supported through a simple HTML interface, enabling real time data to be both displayed and updated from a standard web browser. The module features a fully

integrated 10baseT Ethernet interface and both RS232 serial and I^{2}C ports for interfacing with host systems and I/O modules. PicoServ supports the following protocols: Ethernet, ARP, IP, ICMP, TCP, UDP, HTTP, TFTP and DHCP. The TCP implementation is socket based and can support 16 simultaneous connections while the inclusion of a DHCP client simplifies module configuration to 'plug and go' when a DHCP server is available.

Measuring only 50mm x 70mm (2" x 2.75") the PicoServ web server is available as an OEM module or can be used as a stand-alone system when housed in an optional tough aluminium enclosure.

In addition, a number of stacking, standard intelligent interface modules are also available which provide 'no develop-

ment' parallel, serial, analogue, and digital I/O interfaces between the server module and the outside world.
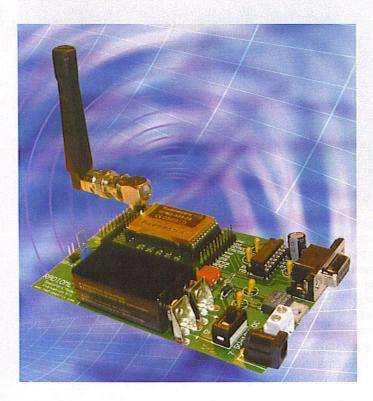
**Compulogic Limited,
Cranfield Innovation Centre,
University Way,**
Cranfield Technology Park,
Cranfield MK43 0BT.
Tel. +44 (0) 1234 756048,
fax: +44 (0) 1234 757731.
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enquiries@compulogic.ltd.uk
Web: www.picoserv.com

(047006-1)

SpacePort Modem Evaluation Kit

The latest from low power radio expert Radiometrix is its new SpacePort modem (SPM) evaluation kit. This has been designed to test the company's low-cost and highly

integrated bi-directional wireless serial interface module - the SPM. The evaluation kit makes testing in application fast, simple and accurate.

The SpacePort modem is an

OEM product that can be easily incorporated into both new and existing designs and it uses addressable data packets with error checking, packet acknowledgements and retransmissions to achieve a reliable and invisible wireless data link. Remote configuration is simple. Built for ease of use and rapid installation, the SPM has many applications in point to point telemetry, telecommand and tele-control to / from outstations or machinery, communications to and from PDAs, organisers and laptops, hand-held / portable terminals, EPOS equipment, high-end security, dataloggers, environmental monitoring, PLCs and alarm / exception signalling, automatic database interrogation, job allocation and status reporting, automatic location reporting / polling and anywhere wireless RS232 datalinks are required.
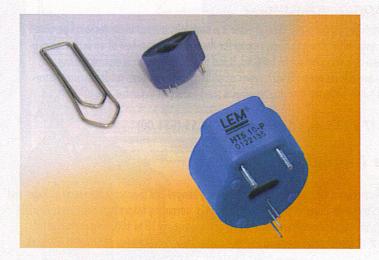
As such, it is important that the SpacePort modem be easily tested for functional integrity when in application and Radiometrix's SpacePort modem evaluation kit will

ensure this, adding to the ease of use and low cost of ownership that is the SPM's hallmark. The new evaluation kit transforms the SPM into a complete radio modem and it features a 5V, 1A supply, ideal for powering up DTE such as barcode scanners. Test operations are made simpler still through the use of optical cues using light emitting diodes (LEDs). An onboard RS232 driver is used for direct serial port connection and a hyper terminal gives access to internal diagnostic and test modes. The hyper terminal also eases set-up and configuration routines. In addition, users of the evaluation kit can gain access to each data / control pin for external interfacing or testing.

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(047006-2)

Miniature PCB-mount Transducers

LEM has introduced the HTS 10-P, the smallest current transducer in its range occupying only 17x19x10.5 mm (L x W x H) on a printed circuit board. Using a unipolar power supply of 0 to +5V, it allows bipolar current measurement of 10 A_{RMS} nominal, supplying a ratiometric voltage output. The initial offset at no primary current (Vdd/2), as well as the gain (Vdd x 20 mV/A) at +25°C are then directly dependent on the supply voltage used. With a measuring range of up to ±15A_{pk}, it is particularly suitable for detecting overloads.

The size, the wide operating temperature range (−40°C to +85°C) and the unipolar power supply targets have been achieved by using an ASIC. The HTS 10-P is supplied with a tolerance of ±12% for the initial offset and ±30% for the gain at +25°C. When the transducer is used with a microcontroller, these tolerances can be improved. Otherwise, the HTS 10-P/SP1 version, with tolerances upgraded to ±3% and ±20%, respectively for the initial offset and for the gain at +25°C, is also available. This version also offers better thermal offset and gain drift.

The performance and low cost of the HTS 10-P series make it particularly suitable for industrial applications (compliance to the EN 50178 standard and marked CE) such as garage door openers; electric doors, gates, shutters and awnings; electric power seats. It is also suitable for low-power, low-cost drives, where the transducer can provide detection, monitoring and safety. LEM Components offers a five-year warranty for each transducer.

**LEM HEME Ltd,
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Tel: (+44) 1 695 72 07 77
E-Mail: kwi@lem.com
Web: www.lem.com**

(047006-3)

SEEVAL® 32 Low-Cost Development Tool

Microchip's new SEEVAL® 32 Serial EEPROM Designer's Kit allows designers to quickly and easily develop robust serial EEPROM-based applications while significantly reducing system integration time and hardware/software debug.

The low-cost kit (DV243002) contains a SEEVAL 32 evaluation and programming board, a CD-ROM with Microchip's SEEVAL 32 software and Total Endurance modelling software, a serial EEPROM sample pack containing eight devices, a user's guide, RS-232 serial cable, and a power supply. The kit provides a powerful programmer/debugger tool that supports all of Microchip's Microwire®, SPI™ and I2C™ compatible serial EEPROMs. It enables users to read, write or erase any byte, block, or an entire array of code. The SEEVAL 32 Designer's Kit runs on any standard PC with Windows® 95/98/2000/Me/XT/NT operating systems.

With the Total Endurance modelling software, designers can quickly identify the best serial EEPROM for their application and perform trade-off analysis with voltage, temperature, write cycles and other system parameters in order to achieve the desired erase/write endurance or product lifetime. This allows the designer to understand and predict the erase/write endurance of the serial EEPROM. An on-line tutorial with hypertext help files is also included.
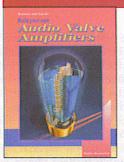
**Arizona Microchip Technology Ltd.,
Microchip House,
505 Eksdale Road,
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(047006-4)

Two Tools for Hundreds of Science Experiments
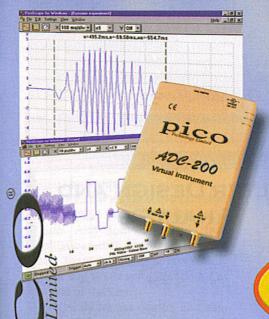
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Analogue Filter Design

By Harry Baggen

In electronics, filters are required for all sorts of applications, ranging from a simple audio circuit to the speech processor in a GSM phone. Filter theory being complex stuff for the average electronics worker and certainly no part of everyday chores, a couple of Internet addresses may come in handy if you're suddenly faced with selecting and dimensioning a filter for an application on hand. In this month's instalment of Electronics Online we look at a dozen or so calculation aids for analogue filters.

Electronic filters represent a complex matter which is not, or not fully, mastered by many electronics enthusiasts. Not to worry, because lots of professional engineers will also admit defeat to the niceties of modern filter design. Fortunately, neither the hobbyist nor the professional worker needs to have a few dozen equations in his head — what matters is to know where the information can be found when it is needed. To help you on the way, and perhaps add a few bookmarks in your Favourites folder, we searched the Internet for software tools that considerably lighten the job of passive and active analogue filter design.
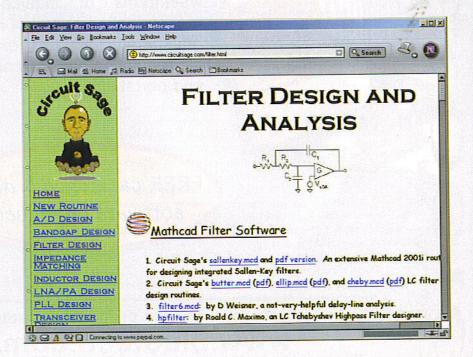
An excellent point to start from when you need filter information in the widest sense is **Circuit Sage** [1]. Set up a number of years ago by a bunch of IC designers, this website covers a vast range of electronic designs. With each subject, the designers themselves make relevant information available, or point the way to other sources on the web. Looking under the heading 'Filter Design' the list starts with a number of calculations intended for use with the familiar MathCad mathematics program. Various types of low-pass and high-pass filters are available in passive as well as active guises.
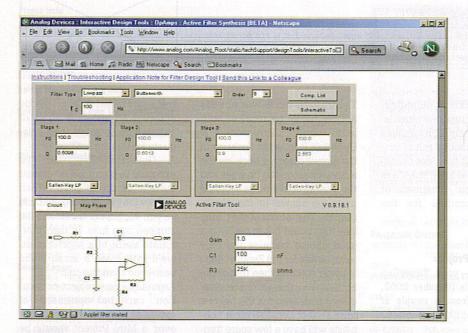
If you can not, or do not want to, work with MathCad, the second list on this web page contains addresses of alternative filter calculation programs.
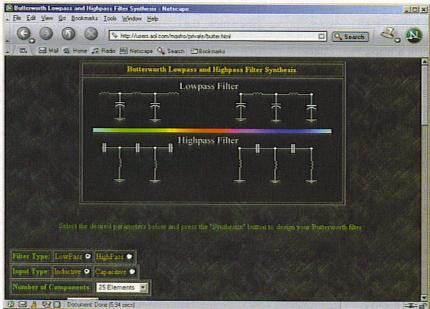
From the latter group we made a selection, with an eye for software that's offered free of charge. We begin with a number of calculation tools that can be run directly off the relevant website.

Analog Devices on their massive website [2] offer a number of online calculation aids for active filters. The scripts allow second-order through eighth-order high-pass, low-pass and band-pass filters to be dimensioned, enabling you to select between filter responses like Bessel, Butterworth and Chebyshev, all with various ripple responses.

A helping hand for passive filter design is offered by various tools on the **Max Froding** website [3]. We found a page discussing the design of passive Butterworth filters (high- or low-pass) with up to 25 ele-

under the name *Burr Brown Filter Designer Software*. These days TI supply a revamped version running under Windows under the name **FilterPro** [6]. The program suite computes Sallen and Key or multiple feedback constellations with a Bessel, Butterworth or Chebyshev response.

Linear Technology [7] also offers a few filter programs that are certainly worth your thorough examination and practical use — the names are **FilterCAD** and the **Filter Design Guides** for the LT1567 and LT1568. Although the programs assume you're using LT integrated circuits, they're easy to adapt to similar products from other manufacturers.

Filterlab from Microchip [8] is another dimensioning program for active Bessel, Butterworth and Chebyshev filters up to eighth order (low-pass, high-pass and band-pass). The program is easy to use, allowing you to view a simulation of the frequency and phase response immediately after the filter dimensioning operation.

Tunekit 2.0 [9] is a small Windows program written by Max Froding. It is suitable for Chebyshev low-pass and high-pass filters comprising 2 to 25 poles, band-pass and notch filters. The program has been designed as a front-end to the famous ARRL Radio Designer and so allows your filter to be analysed straight away.

Finally, those of you interested in 'big gun' programs only should follow these links to demo versions that provide excellent introductions to filter dimensioning: **Filtroid** by Gigasim [10], **Filter Master** by Intosoft [11], **Super Filter** by Those Engineers [12] and **Quickfil** by Omicron [13].

(045005-1)

ments. Another page helps you compute passive elliptical (or Cauer) band filters.

Tony Fishet's interactive **LC Filter Design** page [4] is certainly worth trying. Although graphically less sophisticated that the above websites, Tony's pages look technically sound and it's results that count at the end of the day.

Software for the design and simulation of filter responses has always been pricey. Fortunately, a few programs are available at no cost at all.

To begin with, we should mention Burr Brown's **Filter Perfect**. A bit dated, maybe, but still a great piece of DOS (!) software, it can be downloaded from the **RF Tools** website [5]

Internet Addresses

[1] Circuit Sage: www.circuitsage.com/

[2] Analog Devices Interactive Design Tools: www.analog.com/Analog_Root/static/techSupport/designTools/interactiveTools/filter/filter.html

[3] Max Froding filter calculations: http://users.aol.com/maxfro/private/butter.html
     http://users.aol.com/maxfro/private/cauerbpf.htm

[4] LC Filter Design: www-users.cs.york.ac.uk/~fisher/lcfilter/

[5] RF Tools: http://rfengineer.cc/rftools.htm

[6] FilterPro: http://focus.ti.com/analog/docs/sampleutilities.tsp?path=templatedata/cm/utilities/data/filterpro&templateId=3&familyId=57&navigationId=9742

[7] Linear Technology filter software: www.linear.com/software/

[8] Filterlab: www.microchip.com/1010/pline/tools/analog/software/flab/10626/index.htm

[9] Tunekit 2.0: http://members.aol.com/maxfro/private/tunekit2.html

[10] Filtroid: www.gigasim.com/gsFiltroid.html#anchor647705

[11] Filter Master: www.i-t.com/engsw/intusoft/filtrmstr.htm

[12] SuperFilter: www.spiceage.com/demo.htm

[13] Quickfil: www.omicronsw.com/downloads/swdemos/index.html

Directional Microphone

In Elektor November 2003 on page 26 the author tells us that the low-pass filter frequency is determined by the combination R8 and C3 — this makes me sad. I believe the references should be to C7 and R9 (else I have taught all my students the wrong thing for more than 15 years !).

Also, I wonder, what is the meaning of resistors R19 -R30? As far as I can see they are all paralleled with P2 which is 'only' 1 kOhm. Besides, resistors R37-38 (470 Ohm) will work as RL's — when you look in the data-sheet from TI you'll see that all data are measured at RL> 10 kOhm. I've used the TCL2272 series and found that the distortion of these op-amps will be rather high (>1% at 1 kHz) when RL is smaller than 10 kOhm at an output swing greater than a few hundred milliVolts.

I think it's sad that Elektor Electronics brings articles with such essential faults !
Soeren Ploug, Denmark (by email).

There's no reason for sadness caused by one typo. The reference to C3 in the formula on page 26 is wrong and should have been to C7 (see Corrections & Updates elsewhere in this issue). Still, the two components R8 and C7 are not related to the low-pass filter function, and no such statement is made in the article. Obviously, the low-pass filter roll-off frequency is determined by R9-C7, see also the inset at the end of the article and in particular, equation 16. The function of R19-R30, then, is to prevent audible clicks in the output signal when the rotary switch is operated, which is achieved by providing a DC path to ground for all capacitors C11-C22 when they are not selected by S2. After all, the output of IC1.D is at roughly half the supply potential (you may have missed this point).
Contrary to what you seem to assume, the circuit does not pro-

vide any substantial amplification of the microphone signals. Even at extremely high volumes no more than about 8 mA of output current will flow (not counting the external load), which is way below the maximum of ±50 mA specified for the opamps used.

Flawed Mini Project

Dear Editor — your 'SuperCap Battery' article (October 2003, Ed.) suffers from a couple of design flaws I'd like to mention.

The Goldcap is discharged by R1 and R2, so a diode behind the charger circuit would have been in order. Without such a diode, you will be unable to justify the '2-mA under no-load conditions' claim made in the article, simply because the series combination of R1 and R2 already draws more at 2.3 V. An additional load is formed by the voltage regulator, because current flows into its output.

To use a reverse-biased transistor b-e junction as a Zener diode is ludicrous for a circuit supposed to be reproducible — the Zener voltage will stray far too much. Also, a transistor with higher gain (C-suffix version) would help to reduce the no-load current, as it would have allowed a higher value for R3 (approx. 4.7 kΩ). Diode D2 is clearly under-dimensioned. This diode can be expected to carry high currents as the full Goldcap voltage is applied to the load by way of the coil and the diode. In this position I would have liked to see a Schottky diode capable of passing in excess of 1 A, or failing that, an 1N4002 as the bare minimum. The statement that the coil resistance should be under 1 Ω is incorrect — although it stands to reason that the converter efficiency drops with coil resistance. I would have like to see this mentioned.

Finally, it would have been nice to see a graph with efficiency plotted against output current.
Dr T. Scherer

The missing diode was already noticed before we received your letter (see Corrections & Updates). It failed to show up in the circuit diagram because the author employs the charger and the step-up converter as separate units (as shown in the photograph). The ersatz Zener may look haphazard but in reality is a good choice because the only requirement for the Zener voltage is better stability than that of the battery. Also, the use of a reverse-biased transistor fits the bill of a Mini Project because most hobbyists will have a few spare transistors lying around but no Zener diodes. In our experience, the

transistor-based Zener diode achieves an accuracy of about 10% which is more than adequate for this application.
A Goldcap, then, can be expected to pump a short-circuit current of up to 6 A, which defeats the use of a largish diode as you suggest and can only be stopped by a fuse. In the unfortunate event of a short-circuit, we'd rather see a small diode destroyed than the coil.
Arguably, every project publication can be optimised or extended in some respect. However, a Mini Project should be simple, brief and open to experiments.

CORRECTIONS & UPDATES

Rev Counter for R/C Models
November 2003, p. 56-61, 024111-1.
A 4.7 kΩ resistor should be inserted between pin 7 of IC1 and the base of T4. Without the series resistor, the comparator output is short-circuited to ground by way of the base-emitter junction of T4. The resulting current will however not damage the TLC272.

Electric Charge Meter
November 2003, p. 20-21, 030018-1.
On the PCB overlay, the symbols '+' and '−' near K2 should be swapped. This error does not affect the operation of the circuit.

Directional Microphone
November 2003, p. 24-30, 030046-1.
The equation in the article text on page 26 contains a wrong component reference and should be amended to read:
$R8 = d / (c \cdot C7)$

USB-RS232 Interface
April 2003, p. 60-65, 0200375-1.
In the circuit diagram on page 62, the value of R10 should be amended to read: 100 kΩ. This does not affect the Components List or the PCB layout.

Supercap Battery
October 2003, p. 52-53, 030109-1.
Components IC1, R1 and R2 cause a rather too high discharge current of about 5 mA on the Goldcap battery. This can be prevented by an additional diode between the Goldcap and the LM317.

Please Note

Software items marked @ are available from the Free Downloads page of the Publishers' website at www.elektor-electronics.co.uk.
Diskettes are supplied for the convenience of readers without Internet access.

		£	US $
EVERGREENS			
Elektor Electronics Help Disk			
966022-1	Disk, Windows version	8·15	14.45
Elektor Electronics Item Tracer 1985-2002			
036003-11	contents database (disk, Windows version)	8·15	14.35
Medium power HEXFET amplifier (December 1993)			
930102-1	PCB	10·90	19.25
Universal Prototyping Boards			
UPBS-1	PCB	2·45	4.30
UPBS-2	2 PCBs	4·10	7.25
UPBS-4	4 PCBs	6·55	11.55
No. 328 JANUARY 2004			
64-K 80C552 Flash Board			
@ 030042-1	PCB	9·35	16.55
@ 030042-11	Disk, misc. project software	4·90	8.65
030042-21	29F010, programmed	10·00	17.70
030042-31	GAL 16V8D15QP, programmed	6·10	10.80
Climate Logger			
@ 030076-1	PCB	7·75	13.70
@ 030076-11	Disk, Windows software	4·90	8.65
FMS Flight Simulator Encoder			
@ 030066-1	PCB	10·20	18.05
030066-41	87LPC767BN, programmed	17·05	30.15
LED Roulette			
@ 030168-1	PCB	17·90	31.60
@ 030168-11	Disk, source and hex files	4·90	8.65
030168-41	89C2051-12PC, programmed	8·05	14.25
Multi-event Alarm Clock			
@ 020304-11	Disk, C (source) hex files	4·90	8.65
020304-41	AT89C2051-12PC, programmed	6·10	10.80
No. 327 DECEMBER 2003			
FM Remote Control Transmitter & Receiver			
@ 034044-1	PCB	10·20	18.05
LED Christmas Decoration			
@ 030157-1	PCB	7·55	13.35
P87LPC76x Programmer			
@ 030313-11	Disk, project software	4·90	8.65
Project Timekeeper			
@ 020350-11	Disk, source & object code files	4·90	8.65
020350-41	PIC16F84-10P, programmed	13·15	23.25
Stepper Motors Uncovered (2)			
@ 020127-11	Disk, source code file	4·90	8.65
Universal Clock Generator			
@ 020395-11	Disk, source code file	4·90	8.65
Wireless RS232 Link			
@ 030204-1	PCB	8·70	15.40
No. 326 NOVEMBER 2003			
Rev Counter for R/C Models			
@ 024111-1	PCB	17·50	31.00
024111-11	Disk, source and hex code	4·90	8.65
024111-41	89C2051-12PC, programmed	8·85	15.65
Running Text Display			
@ 020407-11	Disk, source and hex code	4·90	8.65
USB Analogue Converter			
@ 020374-1	PCB	7·65	13.50
@ 020374-11	Disk, hex code and Windows software	4·90	8.65
020374-41	PIC16C765, programmed	13·25	23.45
No. 325 OCTOBER 2003			
DDS RF Signal Generator			
@ 020299-1	PCB, generator	11·60	20.55
@ 020299-2	PCB, control/supply	12·10	21.45
020299-41	AT90S8515 8PC, programmed	30·55	54.05
Minimalist Induction-Balance Metal Detector			
@ 020290-1	PCB	8·95	15.85
Xilinx PROM Programmer			
@ 010109-11	Software	4·90	8.65
No. 324 SEPTEMBER 2003			
ATV Picture Generator			
@ 020295-11	Disk, source & hex code files	4·90	8.65
020295-41	AT90S8515-8PC, programmed	15·20	26.90
020295-42	AT90S1200-12PC, programmed	13·90	24.60
DTMF Remote Telephone Switch			
@ 020294-1	PCB	11·65	20.60
@ 020294-11	Disk, project software	4·90	8.65
020294-41	PIC16F84A-20/P, programmed	14·70	26.00
LC Display with I2C Bus			
@ 030060-2	PCB	7·35	13.00
PICProg 2003			
@ 010202-1	PCB	9·05	16.00
@ 010202-11	Disk, Windows software	4·90	8.65

			£	US $
010202-41	PIC16F874-20/P, programmed		23·55	41.65
Polyphonic Doorbell				
@ 020354-11	Disk, project software		4·90	8.65
020354-41		PIC16F84A-10/P, programmed		14·45
25.55				
Precision Measurement Central				
030060-91		Ready-assembled & tested board		69·00
112.50				
Valve Preamplifier (1)				
@ 020383-1	PCB, amplifier board		11·55	20.40
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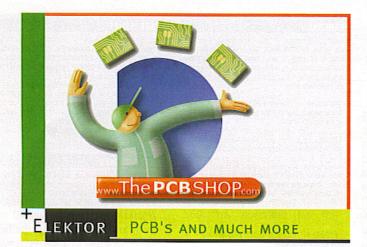
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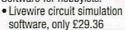http://www.mqpelectronics.co.uk
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